MAN AND HIS ANCESTORS

IN this little volume the author brings together and presents to the reader in simple and readable form the more salient of the factual proofs science has gathered in support of the doctrine of organic evolution and the ascent of man from lower forms of life.

Because of the prominence given just now to these questions, this little book will be found informative and serviceable to all who may desire to gain an intelligent grasp of the subject, but whose lack of scientific training or whose preoccupations hinder them from making first-hand investigations for themselves.

The subject is so treated and the evidence so presented that the reader may form his own conclusions if he is not satisfied with those drawn by the author.

..By..

Chas. Hill-Tout

F.R.S.C., F.R.A.I., Etc.

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with the Author's
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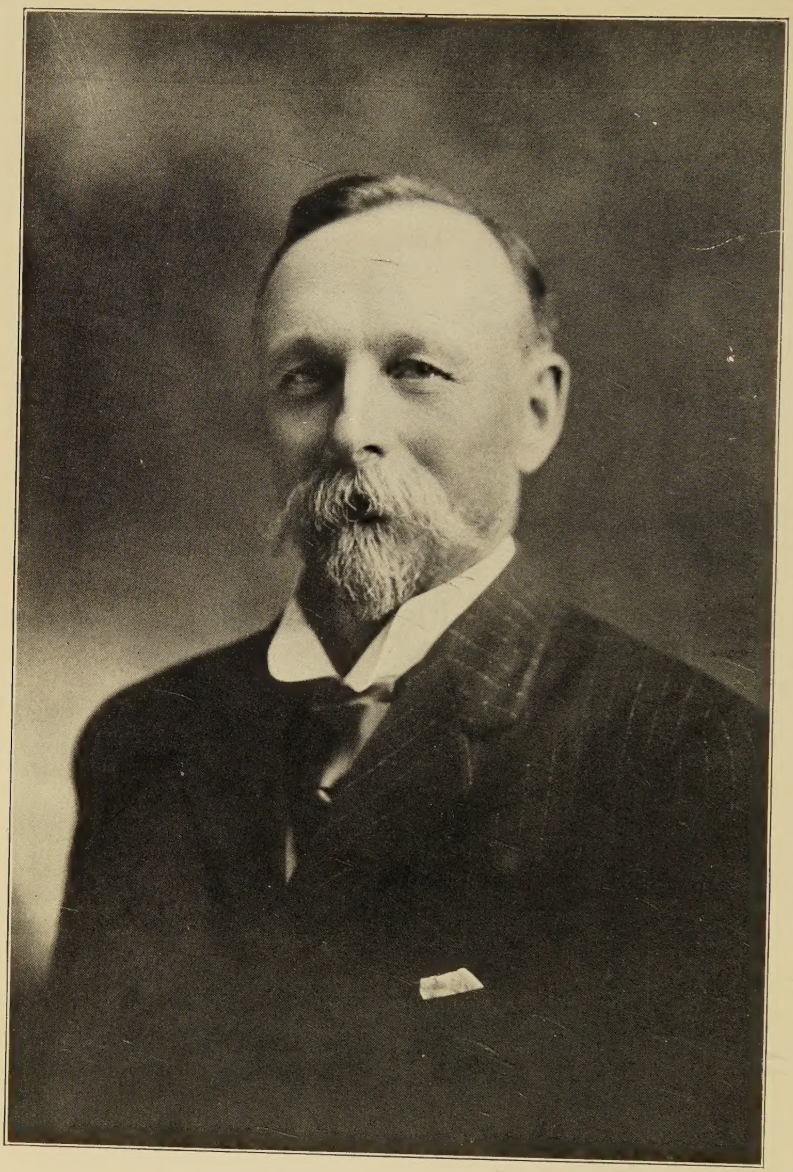

CHARLES HILL-TOUT.
F.R.S.C . F.R,A.I.. Etc.

Man and His Ancestors In the Light of Organic Evolution

BY

CHARLES HILL-TOUT

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THIS LITTLE VOLUME IS DEDICATED TO

TRUTH

MAY TRUTH EVER PREVAIL, NO MATTER WHOSE OPINIONS SUFFER THEREBY, OUR OWN OR OTHERS.

"Read not to contradict and confute, nor to believe and take for granted * * * but to weigh and consider."—Bacon.

"The man who will not investigate both sides of a question is dishonest."—Abraham Lincoln.

most unmistakable manner that the writers are out-and-out unqualified advocates of evolution.

One hesitates to charge them with conscious dishonesty and a deliberate intention to deceive—for many of them are ministers of religion—though their statements at times certainly give one this impression. There is, therefore, no alternative left but to suppose they are laboring under a deplorable misapprehension of what the doctrine of organic evolution teaches and stands for. Few of them seem to have any first-hand knowledge of the books from which the quotations have been drawn, or they could not fail to realize that the meanings and interpretations they have sought to give to these passages are the very opposite to those which the writers themselves hold, or would wish to convey to their readers.

They display also a most lamentable confusion of ideas concerning the basic problems of biology. They seem to be wholly unaware that the "fact" or principle of organic evolution, and the "factors" or causes which underlie it, are two totally different questions, and must be treated as such; that while there may be differences of opinion about the "factors," there is no doubt at all in the mind of a single biologist of standing about the "fact" of organic evolution. Biologists everywhere are in absolute agreement on this point, whatever differences may be found among them on others; and all are in accord with the terms of the manifesto referred to above, which expressly states that "no scientific generalization is more strongly supported by thoroughly-tested evidence than is that of organic evolution."

They persistently confuse these two ideas, so fundamentally different, and regard them as one and the same, with the consequence that they draw the totally unjustifiable conclusion that because this biologist or that no longer accepts certain of the older Darwinian views with respect to the operative factors in organic evolution, he has thereby rejected the principle or "fact" of organic evolution itself, a conclusion than which nothing could be farther from the truth.

It is this confusion of ideas which seems to prevail so widely in the public mind at the present time concerning organic evolution that has prompted the publication of this little volume, the aim of which has been to bring together and set forth in language as little technical as possible some of the more striking and significant portions of that large body of evidential facts upon which biologists and others have founded their belief in the principle of organic evolution.

It has seemed to the writer that all who will bring an open and unprejudiced mind to a consideration of these evidential facts as we know them today, and also have a desire to reach the truth, must be led to agree with the conclusion reached by the learned

priest and biologist, the Rev. Father Wasmann of Berlin, after many years of study of biological problems, namely: that the only reasonable and satisfactory explanation of that bewildering variety of form to be found in the world of life today, and of the transformations and mutations the geological record shows us have been continuously taking place all down the ages, is the illuminating principle of organic evolution.

The chapter dealing with fossil man and his early physical characteristics will be found to present views somewhat different from those which have prevailed generally up to the present time.

Much new knowledge, to which the writer has been privileged to make some slight contribution, has come in from various sources in recent years which has modified our views on many important points, especially as to the age of man and his primitive characters. This new evidence is here briefly set forth, together with the conclusions to which it seems to him to lead us.

As will readily be seen, the title of this book discloses the views held by the writer on the vexed question of man's descent from lower and earlier forms of life. As he regards the evidence for this genetic relationship, no other view seems logically possible to him. But in accepting this view he desires emphatically to say that it does not conflict with, or in any way affect, his firm belief in the existence of a moral and spiritual world, and moral and spiritual influences, unless it be to confirm and strengthen it.

The physical side of man's nature is one thing, his moral and spiritual side quite another; and all the experience of human life goes to show that the latter cannot be less real than the former. And just as his body, and the bodies of his long line of ancestors, near and remote, have responded to the influences which operate in the physical world, so has his mind and his spirit responded to the influences which work in the moral and spiritual world, until he is what he is today. As we know him at the present time, he is equally the product of the influences of both worlds, insofar as they have been able to affect and mold him.

University Club,
Vancouver, B. C.,
Feb. 12th, 1925.

Contents

Page

Foreword - - - - - - - - - - - - 5

CHAPTER I.

The Universality of Evolution - - - - - - - 9

CHAPTER II.

Foundational Laws of the Organic World - - - 12

CHAPTER III.

Life; Its Nature and Source - - - - - - - 17

CHAPTER IV.

Life; Its Nature and Source (Continued) - - - 22

CHAPTER V.

When Did Life First Appear on Our Globe? - - - 28

CHAPTER VI.

The Nature of the Evidence of Organic Evolution - - 33

CHAPTER VII.

Micro-Organisms - - - - - - - - - - 39

CHAPTER VIII.

Bacteria - - - - - - - - - - - - 44

CHAPTER IX.

Fungi - - - - - - - - - - - - - 49

CHAPTER X.

Reproduction, Regeneration and Rejuvenation - - - 55

CHAPTER XI.

Algæ - - - - - - - - - - - - - 62

CHAPTER XII.

The Protozoa - - - - - - - - - - 69

CHAPTER XIII.

The Protozoa (Continued) - - - - - - - 73

CHAPTER XIV.

The Metazoa - - - - - - - - - - 79

CHAPTER XV.

The Earliest Vertebrates - - - - - - - - 85

CHAPTER XVI.

The Amphibians - - - - - - - - - 90

CHAPTER XVII.

The Reptiles - - - - - - - - - - 96

CHAPTER XVIII.

The Mammals - - - - - - - - - - 101

CHAPTER XIX.

The Horse, the Marine Mammals and the Primates - - 107

CHAPTER XX.

Embryological Evidence of Man's Lowly Descent - 113

CHAPTER XXI.

The Anthropoids and Man - - - - - - - 118

CHAPTER XXII.

Vestigial Structures - - - - - - - - - 127

CHAPTER XXIII.

Serology or Blood Tests - - - - - - - - 132

CHAPTER XXIV.

The "Factors" of Evolution - - - - - - - 137

CHAPTER XXV.

Conclusion - - - - - - - - - - 152

CHAPTER I.

The Universality of Evolution

THE progress of human thought, when rightly considered, is seen to be essentially the history of the succession of a long series of dominating ideas.

It requires but little reflection to see that the human mind is dominated and controlled entirely by the ideas which find lodgment within it. One has only to cast one's thoughts back over the history and development of religious conceptions, and recall the influence they have exercised at all times, over men's minds and actions, to find abundant evidence of the truth of this statement.

The progress of the Sciences illustrates equally the same fundamental truth. Every now and again some outstanding genius, some superman, arises who gives to the world some illuminating concept—some great generalization—which pours a flood of light into the dark places of the human understanding and makes intelligible and clear for us things and principles which before were dim and obscure. Such a superman was Newton. His formulation of the law of gravitation brought such light and order into our conceptions of the universe that it can be justly said of him that before his time the universe was without form and void; and where before was only darkness, light now shines.

To have perceived a law applicable not only to terrestrial matter, but also to the planets and sun and all the starry hosts of heaven, was assuredly one of man's greatest achievements. Such an accomplishment makes manifest, in part, at least, the marvellous powers which lie dormant in the human mind awaiting unfoldment. And while there has been no lack of geniuses since Newton's time, there is perhaps only one other who ranks with him in the wide influence his conception has exercised in the domain of human thought, and that is that remarkable personality of the last century—Charles Darwin.

Darwin's contribution to human thought was the establishment of the principle of evolution upon a factual basis. Contrary to the popular notion, the idea of evolution did not originate with Charles Darwin. It is as old at least as the Greek philosophers. What Darwin did was to bring the concept of evolution out of the hazy realm of speculation and establish it as an actual working principle in the universe upon a basis of fact. He did this by applying the principle to organic life. He was the first to furnish adequate and factual proof of an evolutionary process in nature. His great epoch-making book, "The Origin of Species," ranks with Newton's "Principia" in its illuminating and unifying power; and although Darwin applied the evolutionary principle more particularly to the problems of biology, in the hands of others, it has proved a master-key to the solution of a host of kindred problems, and has brought light and understanding in other departments of human thought where before was only a confused and perplexing mass of seemingly isolated and unrelated facts.

The Doctrine of Evolution, taken in its widest application, is, indeed, even a greater discovery than Newton's; for it is the law of laws—the foundational principle of the universe —gravitation itself being included within the sphere of its activity. Nothing in the universe seems exempt from the operation of the law of evolution, and nothing illumines the dark

places of our human understanding so much, or enables us to realize so clearly and fully the power and transcendence of that Intelligent and Creative Principle which lies behind, and is imminent in all existence, as this universal law of evolution, or unfoldment. And that such a general law exists and is universally applicable has been made abundantly clear, during the past quarter of a century, in relation to the constitution of the heavenly bodies generally, and of our own world in particular.

Modern Astronomy has advanced so rapidly of late years that astronomers are now able to show us worlds in the making; and we may perceive and understand how such bodies as our own sun arise by gradual development or evolution from the diffused and invisible star-dust of space to visible nebulous masses; and from these whirling and condensing bodies again to individual suns and planets. We may now actually watch the process of world-making stage by stage; for in the immensities of space there are unnumbered bodies in every phase of development or evolution, from condensing star-dust to such mighty orbs as Betelgeuse, and from these to declining and darkening suns. We are told there are as many of these latter, which have run their course, as of luminous bodies. We even know the present phase through which our own sun is passing. We are certain that it has long since reached the zenith of its splendour as a luminous body, and is now gradually sinking into the obscurity of old age, and will one day become one of the dark and invisible bodies of space. In a very real sense we may speak of the celestial bodies of space as passing through their periods of birth, youth, maturity, old age, and finally, decay. They do all this in their own way as surely as do the forms of life on our earth. Evolution, the law of endless, unfolding and integrating change, is everywhere the law of existence.

In the same way the science of terrestrial physics illustrates this same general law of evolution. Matter is now no longer regarded as that indestructible substance or entity it was formerly thought to be. We now know that it can vanish out of existence or be transformed into something from which all the known characteristics and properties of matter have disappeared. Instead of being distinct from energy—a something to be influenced and affected by it—in its last analysis it now becomes one with energy itself; the two entities being but different phases of one and the same thing—that invisible and intangible something, a great physicist has called the Ether of Space; matter now being regarded as the static expression of this unseen substratum of the universe and energy as its dynamic expression.

Out of this primeval womb of nature, the source of both matter and energy, we may thus perceive how our material universe has been called into being, and been built up stage by stage. In other words, how it has been evolved from something relatively simple and primordial to its present complex and multifarious condition. First appear those primal elements of matter we call electrons and protons. These combining in groups make up and constitute, according to their number and configuration, the different substances known to chemistry. These are the "atoms" of matter. Groups and combinations of these make up and constitute the molecules or larger particles of matter, and these combining again make up the molar forms of matter familiar to our senses.

Thus, wherever we look in the universe, we find the law of evolution is being manifested by the operations we perceive going on there.

It is this very character of universality which manifests itself so widely that forms one of the strongest arguments on behalf of the Doctrine of Organic Evolution. It creates in our minds a strong presumption wholly in its favor; for it is quite unreasonable to suppose that what is observed taking place everywhere else in the universe, is inoperative in, and

excluded from, that particular portion of it we term the realm of organic matter. Our reason rebels against such a view.

Accepting evolution, then, in this general sense as a demonstrable fact in the universe, we need not regard Organic Evolution as something standing alone by itself, a strange and isolated fact, but as merely a specific case in the realm of life of a principle that is as wide and as general as the universe itself.

And now before we proceed further in our consideration of the evidence of evolution in the life-realm let us first come to a clear understanding of just what is meant by the term "Organic Evolution." This is important, for no term seems to have been more misunderstood than this, and much confusion and needless controversy has arisen as a consequence.

By Organic Evolution, then, we mean the gradual unfolding and branching out into a multitude of divergent forms, of a single, primal life germ, which came into existence on this globe, or which manifested itself here, in the dawn of earth history. In other words, that the stream of life has been continuous and unbroken from the first appearance of organic forms on this planet down to our own times; and further, that every living form that has ever existed in past times or which now exists—man himself included—has arisen from, and is genetically related to, some earlier pre-existing form.

This is the law of life as conceived by Darwin and applied by him to the problems of biology; and this is what we understand and mean by the term "Organic Evolution."

Viewed in this way the doctrine of Organic Evolution is seen to be a wholly reasonable and illuminating idea, and worthy of the profoundest consideration of every thoughtful and truth-seeking person.

This scientific conception of life and of living things opposes itself directly, as will readily be seen, to the so-called Mosaic story of the creation and first appearance of life-forms on this globe, as related in the two first chapters of the Hebrew Scriptures. It is none-the-less worthy of our regard on that account And when our readers have taken into careful and open-minded consideration the evidence we propose to set before them in the following chapters, we think they will agree with us that the only possible conclusion to be drawn from this evidence is that an active evolutionary process has been steadily at work in the organic world from the dawn of life on our globe down to the present time; and that such a process is the only reasonable explanation that can be offered to account for the astounding and bewildering diversity of life-forms we find about us.

CHAPTER II.

Foundational Laws of the Organic World

IT WAS shown in the last chapter that the Doctrine of Organic Evolution was a wholly reasonable hypothesis, and was just a specific case in the realm of organic matter of that general law of evolution which is found in operation everywhere throughout the universe.

In this chapter, we propose to consider our subject from another angle. We have satisfied ourselves of its reasonableness, now let us inquire if there are any grave objections to be urged against it on the ground of impossibility. Is there anything impossible in the Doctrine of Organic Evolution? Is there anything in nature which effectually hinders the operation of the law of evolution in the world of life? Is the organic world so differently constituted from the inorganic that the fundamental law which rules in the latter is excluded from the former?

We have no hesitation in saying there is absolutely nothing to lead to such a conclusion. On the contrary, what we find going on there makes such a law of unfoldment not only possible, but highly probable; nay, indeed, inevitable.

Look at the living things about you and what do you see? Everywhere infinite variety of form and function. No two organisms are ever quite the same; they will be found to differ from each other in some respect or other. Out of the myriads of leaves on a tree, for example, not even two of them are ever identically alike. How comes this about? What is the cause of this difference in life-forms? There must be some far-reaching cause at work to produce such widespread results. There is. It is the working of another fundamental law, one of the three great foundational laws we find operative in the organic world.

These three laws together control and rule the world of life and lie at the basis of all we see going on there. They are known to biologists as:

(First): The law of Reproduction; that is the passing on of living substance from one generation to another —a law which manifests itself in various ways, as we shall later see.

(Second): The Law of Heredity— that is the transmission of parental forms and characters; in other words, the tendency of like to produce like, for the offspring to resemble the parents. This is the conservative principle in nature.

(Third): The Law of Variation, or the tendency in the offspring to vary and break away from the parental forms. This is the active or radical principle in nature.

These two latter laws are in direct opposition to each other, and it is the conflict ever going on between them —the nice balancing of their opposing tendencies—which has on the one hand wrought all that wonderful variety of form found today in nature; and on the other maintained the typical forms with sufficient conservancy to enable us to bring resonable order into their multitudinous array by means of a systematic classification in which they are arranged according to their genetic relationships as far as these are known.

This conflict of laws, this contending of opposing forces, is not peculiar to the organic world. We may perceive the same thing going on in the inorganic world, in the opposing forces

which keep the planets and other heavenly bodies in their courses; that is the centrifugal and the centripetal forces of the universe.

It is the operation of this third law, this radical principle in nature, the law of variability—which makes possible organic change. It is the foundational fact which justifies our belief in the Doctrine of Organic Evolution, and upon which it has been established.

It is a principle or law seen in operation everywhere in the world of life today. It is illustrated every time a new organism arises or comes into being. It is happening all the time and must have so happened since the dawn of life. It is as fundamental a principle as the law of Heredity or the law of Reproduction, and must have come into operation when they did.

Even the Creationists and Fundamentalists have to admit this. The fact of variability cannot be denied by anybody. But realizing that the law of variation is the groundwork upon which Darwin founded his "Origin of Species," and that it is the strongest argument against their own views, they seek to get over this difficulty by unjustifiably imposing limitations of action upon the law of variation. As they cannot deny its existence, and its operations, they would discredit its powers and limit its action. They contend and declare that this power to vary and change, resident in all organic forms, is extremely limited in operation and confined to very narrow lines beyond which it cannot go. That from its working merely "varieties" of the same kind of organism are produced and never distinctly—new forms or "species;" thus begging the question at the start and befogging the issue in a terminological dispute. For who shall say or decide exactly when a new variety or a new race of plants or animals ceases to be merely a "variety" or "race" and, by a continued succession of changes and modifications, becomes a new "kind" or "species" of plant or animal?

Botanists and Zoologists alike declare that they have definite knowledge, arising from their personal observations and researches, of what are commonly termed simple varieties and races changing, by modification of characters and functions, into what science commonly regards as "systematic varieties" or new species.

We could quote the works of a host of biologists along this line, but we will content ourselves here with just two pertinent citations; one taken from the science of Zoology, the other from the science of Botany. Later on this question of varieties and species will be dealt with at greater length.

The first is taken from "The Problem of Evolution" and "Instances of Recent Formation of Species," two of the writings of Father Wasmann, who besides being a zealous Jesuit priest, is also a distinguished biologist. We quote from Father Wasmann's works preferably because, being a priest, he cannot be said to favor the Doctrine of Evolution at the cost of Scriptural truth.

His special research has lain among those insects known as Inquilines. The inquiline is a kind of beetle which, from having taken to live among colonies of ants, has become so modified by accommodation to the new conditions of life, that it has lost most of its original characters and acquired wholly different ones in their place. These modifications are so radical and so deep-seated, that not only new "species" have arisen, we are told, but also new "genera" and new "families." "In some cases," writes the learned Father, "the characteristic marks have been so completely altered by accommodation to the life of the ants that it is scarcely possible for us to determine to what 'order' of insects these strange creatures belong. In other cases, the whole development of the individual is modified in such a way that it resembles the modifications of a viviparous mammal rather than those of a fly."

Most of these beetles which have been admitted as guests by the ants can be divided into three biological groups. First there are the true

guests which are tolerated and fed by the ants, because they are able to exude an aromatic substance which the ants enjoy licking. These are the "paying guests."

Then there is a second class known as the ant-ape. It lives among the blind wandering ants of Brazil, and is enabled to pursue its parasitic existence among them because it bears a remarkable resemblance to the ants themselves, in the form of its antennae and of its whole body. The ants' sense of touch, which lies in their antennae, is thus deceived by this resemblance.

And lastly a third class, which is a kind of beetle that is protected by a shell covering against any attack on the part of the ants.

These creatures, according to Wasmann, have all been evolved from the same "family" of Brachyoptera—that kind of beetle which has short wing-cases—although they differ in form from one another at present more than an ape differs from a tortoise.

After dealing with the evidence for the transformation of these beetles and other strange guests of the ants, he concludes his remarks in the following significant words: "What conclusions are we to draw from these considerations? If we carefully study the phenomena which have just been presented to us, we must acknowledge that only the theory of evolution can explain to us how these interesting forms came into being. We cannot supply a scientific explanation by merely declaring that these strange little creatures, such for instance as the Mimeciton or ant-ape, were created by God expressly for this or that variety of ant. The principle of the theory of evolution is the only one which supplies us with a natural explanation of these phenomena, and, therefore, we accept it."

We will conclude our citations from the learned Father's writings with one more short quotation. It has reference to his remarks about Science and the Scriptures: "We must first of all state clearly," says he, "that the Bible is not intended to instruct us in modern science; and we scientists of the twentieth century ought not to seek zoological information in it. The Bible is meant to give instruction not on science, but on the way of salvation." We commend this very pertinent statement of the reverend Father to the consideration of our Fundamentalist friends. It seems to us to hit the nail straight on the head.

Our second citation is from De Vries' "Species and Varieties." In this volume, De Vries, who is a Dutch botanist of note, gives us an account of his experiments with a plant called Œnothera lamarckiana by science, but which is known to the lay mind by the more familiar term of "Evening Primrose."

This plant is an American form which has been carried to Europe and is now found growing there in a wild state. De Vries found such a wild variety near Amsterdam; and some time after his first discovery of it noted the appearance of two well-characterized forms which he recognized at once as new elementary species. One of these was that which is now known as O. brevistylis. The other was a smooth-leafed form with a much more beautiful foliage than the parent form O. lamarckiana. This we now know as O. laevifolia. Experimenting with these two forms he found they bred true from self-fertilizing seeds. He placed all three forms under observation, and from the three kinds of plants—the parent and the two daughter forms — there have arisen the three groups of new families of elementary species now well-known to botanists the world over.

As we shall have to consider these observations and experiments of De Vries later on when we come to deal with the problems of "continuous" and "discontinuous" evolution, it will suffice here to point out that the unique feature of the changes or mutations in this Evening Primrose was the constancy with which the new form was inherited by the offspring; showing thereby that it had passed the

stage of a simple variety and had become a new and distinct form or "species" with heritable qualities.

From these instances—to which might be added many others from both life kingdoms, and in particular the breeding experiments of Prof. T. H. Morgan and his able corps of coworkers, with the fruit fly, where we find scores of new forms or "mutants" coming into existence—it becomes quite clear that the limitations the opponents of our doctrine would impose upon the law of variation, have no real weight or force; and, given the necessary conditions, this law of variation—working at times through "continuous evolution" as conceived by Darwin, at others, by "discontinuous evolution" or "mutations," as conceived by De Vries, Morgan and others —is quite competent to have produced, from a simple primordial life-germ every distinctive form of life that has ever existed or which now appears in the world about us.

If this be not the function of this fundamental law or principle of variation, what then is its purpose in nature? Why do we find it actively operating throughout the realm of life? It serves no other useful purpose that we can discover if it be not the cause of those differences which distinguish one living form from another, and also the true explanation, as Father Wasmann pointed out, of the origin of systematic varieties otherwise called "species," etc.

Our opponents will probably reply, as they often have, a sufficient purpose is subserved by making the world more beautiful; that it is this very law of variability which imparts to nature her beauty and her ability to charm and thrill us. It may seem to some at first sight that this is a sufficient purpose, and that the principle of variation has exhausted and fulfilled its function when it has given us an endless number of minor variations in order that the eye of man may rejoice and find pleasure in the handiwork of the Creator; in other words, that our esthetic sense may be heightened and gratified.

But there exist two grave objections against taking such a view of the function of so fundamental and far-reaching a law as this, and restricting its operations to such narrow lines.

Such a view is entirely out of harmony with what we have learned of the working and purpose of the fundamental laws which govern the processes taking place in our universe. If the study of nature has taught us any one thing more clearly than another, it is that she is exceedingly economical, even niggardly, in her schemes and plans and operations. We find her employing the same structural plans again and again in quite different forms. She changes old functions into new ones as the organism evolves. She makes over old material into new, as in the case of the caterpillar and the butterfly, and converts discarded organs into new ones when need arises, a noted example of which is the varied uses to which she puts the branchial arches in the embryo of the vertebrates; or the various functions to which she puts certain organs of the body, making them fins in one creature, flippers in another, wings in a third, fore-legs and feet in a fourth, and arms and hands in a fifth.

In her travails there is never any waste of effort; mountains are never employed to bring forth mice, nor does she produce a cataclysm to kill a fly. The results are always proportionate to the causes; but this could not be said to be the case if such a fundamental law as variation everywhere shows itself to be, had for its purpose merely the gratification of man's esthetic sense—a sense, too, be it observed, very poorly developed or, indeed, wholly absent, in a large portion of the human race.

Besides, when they take this view, they overlook entirely the microscopic world. The same law of variation is to be seen at work there, and the same variety of forms may also be observed among these microscopic forms. The offspring there are never quite like the parent forms any more than they are in the world of normal vision, only being relatively much

simpler organisms, there is not the same scope for change and variation among them. They forget also the very significant fact that this world of micro-organisms actually constitutes the larger portion of the realm of life, in point of numbers; and as by far the greater number of these tiny plants and animals are much too small to come within the range of our vision, some indeed being beyond even the range of our microscopes, it looks to us like a pure waste of effort on the part of nature to find the law of variation as actively at work here as in the world of visibility, if its purpose and function be merely to heighten and gratify man's esthetic sense. We repeat again this is not nature's method of working, and we are driven to seek for a more satisfactory and reasonable explanation of the universal presence and operation of this law in the realm of life than this.

If we view the principle of variation with open and unprejudiced minds, we shall realize how great and important was the discovery made by Darwin when he saw in the working of this law the mechanism, aided and supplemented by the principles of Natural Selection and Adaptation, by which we could rationally explain the origin of the systematic varieties of life-forms.

It was upon the law of variation that he founded and established his great generalization of organic evolution; and although much divergence of opinion has since arisen among biologists as to the "factors" or causes which underlie this inherent power of variation and response in living organisms to internal or external influences, the great central truth of Organic Evolution is now universally regarded as the basal fact in the science of Biology.

From what has been said in this chapter it becomes clear that there is nothing antecedently impossible about the Doctrine of Organic Evolution; but rather, that when it is considered in the light of that fundamental principle of Biology, the Law of Variation, it becomes not only a highly probable process, but virtually an inevitable one.

In the next chapter we will consider the principle of life itself from the point of view of its nature and origin, and see if there be anything in this connection which conflicts with the Doctrine of Organic Evolution, or whether we may not draw support and confirmation in its favor from this quarter also.

CHAPTER III.

Life: Its Nature and Source

IN the last chapter, we considered the Doctrine of Organic Evolution on the ground of its possibility and found there was not only nothing antecedently impossible about it, but that when considered in the light of that fundamental principle of biology, the law of variation, it became not only a possible process in Nature, but an inevitable one.

In this chapter we will consider the question of the nature of life and its origin on this globe and learn, as far as we may, under what conditions it first manifested itself here; and what evidence of the truth of our doctrine may be gathered from this angle of the inquiry.

What, then, is this phenomenon, this something we call life? What do we positively know about it after all our modern studies of it and our investigations into its processes?

What have we learned concerning its essential nature and origin?

If we are frank and sincere, we shall have to admit that we know practically nothing about either its essential nature or its source and origin. Up to this time, it has transcended the powers of science to discover its secret, and most of its mysteries still evade our closest scrutiny.

It is true we have learned much about its manifestations, its laws and its processes; but of its essential nature or its source we know no more today than we did fifty or a hundred years ago.

We know a good deal about the chemical elements which constitute the material basis of life. We can even build up and put together the components of that elemental substance or material substratum of life we call "protoplasm," but we cannot bring our colloids to life, and what life is itself and how and whence it came remain still impenetrable secrets for science. We cannot bridge the chasm we find between non-living and living matter. It is true that there are those who think we are on the brink of achieving this; but others of equal authority in biological science disagree with this view and think it quite unlikely that science will ever be able to close the gap and reveal to us the secret of life.

However, much speculation has been indulged in on the subject, and scientific men hold various opinions upon it. Of these there are three views or concepts that stand out from the rest; and it will be well for us to consider them shortly in this chapter in order that we may get a clear understanding of just what men of science think and hold upon this subject, remembering always, of course, that the well-established facts of science themselves are one thing, and the speculations of scientific men quite another; a fact sometimes lost sight of in the heat of discussion.

The two older of these views are not at all modern concepts. They are ideas which in some form or other were probably as familiar to the old Greek philosophers as to ourselves; but in our day, with our more exact knowledge of nature and its processes, they have taken on distinctly modern aspects.

These two views are commonly known as the Mechanistic and the Vitalistic concepts of life. The third seems to be quite a modern idea, recently enunciated and advocated by H. F. Osborn, an eminent American palæontologist, in his "Orgin and Evolution of Life," and is called "The Energy concept of life," or may otherwise be described as the theory of

the action, reaction and interaction of Energy in relation to life.

As volumes have been written about these theories of life, especially of the two older ones, it is clear we can do no more here than briefly outline their chief features and point out their radical differences.

The Mechanistic view, then, in its modern form, regards life, as its name implies, as the result of the operations of blind, unintelligent forces; and holds that living matter arose slowly and gradually out of, and in consequence of, the increasing complexity of non-living chemical compounds. The Mechanist believes that in the evolution of matter a stage was at length reached when it ceased to be inorganic or non-living and became organic or living. It should be stated that these chemical compounds, from which life is thus supposed to have sprung, form the most highly-organized and the most complex of inorganic substances; and are known to us as "colloids." This colloidal matter is a diffusable jelly-like substance closely resembling in appearance that basal living matter we call "protoplasm," the growth and evolution of which produces all known organic forms.

But close as is the chemical character and likeness of the two forms of matter, an unbridgable gulf appears to divide them. One is still nonliving, inorganic matter, the other is living and organic; and is able to manifest, under proper conditions, those phenomena we group together and express under the term "Life," while the other is not.

Associated with this physico-chemical view of life was the famous "Spontaneous Generation" theory, otherwise known as the doctrine of "Abiogenesis," which signifies the sudden appearance of life where before no life was; over which so many heated discussions were waged in the last century. Abiogenesis, or spontaneous generation, was then supposed to prevail not only among the lower organisms which were thought to come into being in this way, but also quite extensively among the relatively higher forms of life. But increasing knowledge of life-processes has made this view now wholly untenable, and most biologists of the mechanistic school of thought today hold some form of the concept outlined above with Abiogenesis discarded.

There is, however, a certain active school of biologists, represented by the late Jacques Loeb and his followers, who, while obliged to admit that we have no scientific evidence of the appearance of life by spontaneous generation since it first manifested itself on this globe in the dawn of terrestrial history, still believe in Abiogenesis; and think that life may one day be made to manifest itself anew and appear spontaneously in lifeless matter.

But up to the present, notwithstanding the wonderful experiments this school of research has carried on—among which is the artificial activation or impregnation of eggs in various ways without the use of the male element—and the high hopes entertained by Loeb and his co-workers, it has to be admitted that not a particle of scientific proof yet exists that life and living substance can arise in this manner from lifeless, chemical compounds.

The physico-chemical or mechanistic concept of life, therefore, remains still a concept and nothing more.

To some minds immersed in the problems of physics and chemistry, such a theory may seem reasonable and highly probable, but to others it is quite the reverse.

The other and perhaps more general view, held by the Vitalists, is that there is a vital principle or force distinct from both chemical and physical forces; that life is a thing apart from the substance through which it manifests itself and is an order of entity quite different from any other in the universe. That at some time in the past history of our globe an external and unknown force, called the life-force, invaded non-living matter, when it had reached the highly-evolved form seen in the colloids, and endowed it with what we term life.

Bergson, the noted French biological philosopher, has expressed this view rather happily in his well-known phrase: "Life is consciousness launched into matter." For him and many others, life and consciousness are one and the same thing. And, indeed, each seems to bear the same kind of relationship to, and has a similar reaction, with matter. Life is seen to need matter in and through which to manifest itself in just the same way as mind needs the nervous system and the material brain for its manifestations.

In this way life and consciousness have much in common and might conceivably be regarded as two phases of one and the same principle or entity. All living things, even the lowliest of organisms, exhibit some form of incipient consciousness. They are seen to manifest an awareness of the difference in their environment and to respond in various ways to different stimuli or conditions.

Briefly expressed, and disregarding the several forms or aspects under which it is held by different thinkers, this is the so-called Vitalistic view of life.

The essential distinction between these two current views, is thus seen to be not only a difference of opinion in respect of life itself but also in respect of its source or origin. The mechanistic view holds that life, like consciousness, is merely a function of matter when in certain conditions; and cannot exist apart from matter; is, indeed, the result and outcome of its evolution from the simple to the compound state. The mechanist holds and believes that when matter had reached the colloidal and protein state —which is the stage of the material basis or substatum of living forms— life suddenly and spontaneously appeared. And they frankly admit they are looking foward to a fortuitous moment when this same principle of spontaneous generation of life will manifest itself before their eyes in their laboratory experiments.

We cannot say such a thing is impossible whatever we think. This word has no longer any place in scientific phraseology. If we find ourselves unable to hold the mechanistic view of life, because it will not jibe with our philosophy, all we can say at the present time is that such a momentous event does not seem to us at all probable.

But even were such a stupendous thing to take place, it would not carry us very far. The question of the source and nature of that life would remain just as much in the dark as at present. Its mystery would be none the less. To say life arises by spontaneous generation is only to give the process a name; we do not explain its appearance by so doing, and so are no farther ahead than before.

It is just on a par with the Mechanist's statement concerning the relation existing between consciousness and the brain. Consciousness, according to him, is merely a "function" of the brain-cells, because "mind," like "life," needs a material substratum by and through which to manifest itself.

But it is readily seen that to call mind or consciousness a "function" of the brain, or life a "function" of matter, is not to inform us in any way of the nature of either phenomenon, but only to shift the problem farther back. It in no way solves it.

It is surprising how prone we are to befog and befool ourselves and others by the use of vague, empty phrases. The term "function" used in this sense is one of those phrases. It is as abstract and unsubstantial as the term "consciousness" or "life" itself, which it is seeking to explain. We cannot explain one abstraction by another; the unknown can be explained only in terms of the known and to attempt to explain "life" by calling it a "function" of matter is to explain nothing. It is only to camouflage our ignorance.

We have, moreover, seen that "matter" in its ultimate analysis, is as little definable as life itself; and when we have traced it back to that primeval source of substance and energy—the Ether of Space—we are no

better off than before; we have still to seek a source and origin for the Ether.

It is clear, then, that the chemico-mechanical explanation of life cannot give us a satisfactory answer to our question: What is life and whence did it come? So let us be sincere and admit it.

It seems better, then, in the present state of our knowledge to regard life as something apart from, and subsequent to matter as far as its manifestation on this globe is concerned.

This is not to say that matter is "older" than life. There is nothing in the statement to hinder us from regarding them both as coeval, as they probably are. We need not think of one as existing before the other. But inasmuch as we are unable to apprehend life except in and through matter; and as lifeless, inorganic matter seems to have been evolved before living and organic matter, we are driven by the logic of the case to speak of matter as preceding life.

It is in this sense, then, we may say matter appeared before life; and so regarding it we have no alternative but to think of it as a force or power apart from and external to matter, which at some time in the history of the changes and evolution of our globe, captured and invaded matter; and by this invasion, this union and interaction with it, imparted to certain forms of it, as they became sufficiently organized and adapted to receive them, qualities and characteristics they had not manifested before, and which cease to be manifested whenever this mysterious union is in any way interrupted or broken.

It will not be necessary to consider Osborn's Energy concept of life in detail, because though it differs in form and treatment, it is in essence only another modified form of the Mechanistic view.

Instead of looking at matter and form as they appear to us under the evolutionary process, we are invited to look at this process from the point of view of causality; in other words, to consider the part terrestrial energies have played in the production of life-forms.

It differs from the common physico-chemical concept of life mainly in the stress which is placed upon the causal aspects of organic evolution, and in the pointing out of the part energy, by its action, reaction and interaction, has played in the drama of life, in the upbuilding, moulding and shaping of living forms. But life and living things are with him, as with the mechanist, merely the result and outcome of physical and chemical forces; and he holds with Loeb and his followers that Science need not despair of bridging the chasm existing at the present between organic and inorganic matter, and of determining once and for all whether life is solely physico-chemical in its nature or whether it includes, as the Vitalists hold, an energy or element which makes of life something distinct and apart from all other forces.

To which of these speculative views on the nature and source of life a man will be drawn depends largely upon his intellectual training and his philosophy. The majority of men will find their philosophical objections too strong to accept in full the current mechanistic view.

This becomes evident, we think, from the fact that time and again biologists who began their life-work with strong mechanistic leanings have been led by a deeper insight into the evolutionary processes to abandon these earlier views and adopt some form of the Vitalistic concept, because they find themselves unable to reconcile the Mechanistic doctrine of a blind, unconscious force with the evidence they discover in the evolutionary process of directive plan and final purpose. They feel the need of some principle other than blind force to explain the steady, continuous progress of characters, in definitely directed lines, so plainly evidenced in the fossilized life-forms of past ages.

A notable example of this change of mind is seen in the life of the eminent German scholar, Driesch. Beginning his career as an out-and-out

Mechanist, he has been led by the difficulties of reconciling the facts of evolution with the physico-chemical concept of life, to adopt a more philosophic view; and he now postulates what he terms an "entelechy," that is a kind of inner urging and directing force, which for him lies behind, and is the cause of, that purposive, directive growth and evolution he perceives in the world of life.

It was the same dissatisfaction with the Mechanistic concept of life, which led Bergson to formulate his famous "Creative evolution" idea; and von Nageli his mystical principle of progressive development, and Eimer his directive, determining force. And even among those biologists who are loath to admit an external force or agency such as the thorough-going Vitalist postulates, a very general tendency manifests itself to believe in some kind of definitely directing influence which cannot be found in the Mechanistic doctrine of life.

We cannot pursue our consideration of this deeply-interesting subject further in this chapter, but enough has been said, we think, to give a fair idea of what our leading biologists hold and think with regard to the life principle and its manifestations on this globe; and nothing has come to light in the course of our exposition which militates in the smallest degree against the Doctrine of Organic Evolution. On the contrary, what little we have been able to glean of the nature and source of life, whether looked at from the point of view of Mechanism or Vitalism, is wholly in harmony with this doctrine.

In the next chapter we will briefly consider the problem of life and its presence here from the point of view of a possible origin and source external to our globe, and then we shall be ready to take up our examination of the evidence which Science has gathered from her study of the life-forms themselves in support of the principle of Organic Evolution.

CHAPTER IV.

Life: Its Nature and Source

(Continued)

IN the last chapter we sought to learn what science could teach us of the nature and origin of life, and found that she could utter no definite statement concerning either the one or the other; that up to the present time she had failed to correlate the life-force with any other of the forces of the universe whether physical, chemical or electro-magnetic. That while all other forces or energies were convertible from one form into another, life seemed a thing apart, an order unto itself, unlike and unrelated to anything else in the universe.

We found, too, that the thinkers of all ages had speculated deeply upon its mysteries, and that in our own age there prevailed two opposing ideas or concepts concerning it; that one of these—the Mechanistic—regarded life as merely a function of matter, a manifestation of an inherent property of material substance when in certain definite chemical forms or compounds and when the circumstances were favorable to this manifestation or functioning. And that the other—the Vitalistic—regarded the life-principle as something outside of and apart from matter, which at some time in the past had invaded and united itself with matter; thus changing lifeless, inorganic chemical compounds into living organic substance.

A cursory or superficial consideration of these two concepts may make the former seem much simpler than the latter; for under this view the problem of the nature and source of life is one with the nature and source of matter itself. We have but to find the solution of the latter and the other follows from it. This the Mechanistic doctrine claims to have done by excluding any Creative and Directive Principle from the universe; and by postulating the character of eternity for matter and energy; declaring that they have always existed and must always exist; that everything in the universe—man himself included—is but the result of the interplay of these two fundamental entities, matter and force.

By reason of this apparent simplicity, the Mechanistic concept has always been very attractive to certain types of mind and was very generally held by men of science up to the close of the last century. Since then, however, as was pointed out in the last chapter, a deeper study and a wider knowledge of the life-processes have forced many of our leading biologists and others to abandon the mechanistic view, because it appeared to be so much out of harmony with what they found prevailing in the world of life. Nature, in her life-processes, seemed to them to be aiming at some definite purpose and end, which purpose and end could not be satisfactorily accounted for by any merely Mechanistic theory of life. Also, too many new difficulties presented themselves under this materialistic view. Indeed, for the philosophically minded it raised problems more insoluable than those it seemed to solve.

How explain, for instance, they ask, such an organism as man, who is patently an intelligent and reasoning being, if he be but the outcome of the fortuitous coming together of atoms, the product of the interplay of merely physical, chemical and electrical forces, which are themselves wholly blind and unintelligent? How can this creature of chance, this aggregation of chemical atoms—who by the exercise of his expanding intelligence

has been able to measure the immensities of space and weigh the stars in their orbits—perform these and a host of other equally astounding tasks, if he be but the product and outcome of merely blind, insensate forces? How could he have managed to take out of Nature's own hand the very evolutionary process which brought him into being, and have learned to direct, modify and control it almost as he wills—as witness the multitudinous array of new forms of plants and animals he has of late years produced —if he be not something more than a merely energized, chemical compound, a chance offspring of matter and energy?

How can the effect be so much greater than the cause?

Physics teaches us that a stream can never of itself rise higher than its source. How comes it about, then, that this organism we call man has risen so much above his source, and has been able to take hold of the very forces that wrought him and use and direct and, in an increasing measure, control them for his own ends and purposes? How in other words, could the insensate clay contrive to produce the living, cunning potter? We can understand the potter shaping and forming the clay but how explain the clay shaping and moulding the potter. For that is the inverted order of things the mechanistic doctrine of life forces upon our understanding.

To ascribe such power to matter and energy is surely to give to them the very attributes which the Theist claims for his Deity or Creator—a Principle whose existence Mechanism totally denies and excludes from its universe. It is this very aspect of the Mechanistic doctrine which appears so unphilosophic and is so repugnant to other than Mechanistic minds. For, whatever we may conceive the primal source of life to be, we must at least postulate for it intelligence, because we manifest it ourselves; and because we cannot consistently admit that intelligence can proceed from unintelligence or that an active thinking mind can spring from dull thoughtless matter. Reason and philosophy alike forbid such a view.

For the biologist and others, then, who cannot accept this view, and who perceive some teleological or purposeful end in the evolutionary process, life proceeds from an intelligent source whatever that source may be conceived to be. And if he seeks to find a fuller understanding of what life is, as it manifests itself in the organic world, he may follow Bergson and regard it as consciousness or mind launched into matter, which by its increasing control and direction of matter—as evidenced in the intelligence of the higher forms of life—has manifested and will continue to manifest more and more intelligence or mind; thereby implicitly if indirectly, revealing to us something of the character of its Ultimate Source.

Such a view of life is consonant both with scientific inquiry and philosophic speculation.

But, it may be asked: Can the Vitalist learn anything further of this phenomenon, this principle he calls "Life?" Thus, for example, is it confined to our globe, or is it common to the universe at large? Has it manifested itself on other bodies of space, and where and when did it first appear?

These are all legitimate questions, and follow naturally from the Vitalistic concept of life; and it may not be unprofitable for us to spend a little time in learning what kind of answers men of science have sought to give to these questions.

One of the earliest things men learned about life was that it was rigidly and strictly conditioned; that it could not manifest and maintain itself anywhere and under any circumstances.

Even from the Mechanistic point of view, matter had to reach a certain chemical condition before life could appear. Indeed it is this very character of contingency, this dependence of life upon certain narrow and definite, physical conditions, that first led men to formulate and hold the Mechanistic doctrine. And of these

conditions none seems more important and absolutely necessary than what we call temperature.

Life as we know it, is absolutely confined to a temperature ranging from about 85 degrees (Centigrade) above zero to about 250 below, that is to a bare range of a little more than 300 degrees out of a possible one of millions—a very restricted limit indeed. (The mean temperature of our sun is thought to reach into millions of degrees; and there are hotter bodies than it.) Moreover it is only a very few, and those the simplest and hardiest of organisms, that can stand the temperature at either of these limits without injury. The vast majority of life-forms would perish or their functions would be suspended, long before either of these extremes was reached; the life manifestation of most organisms being practically confined to a range not exceeding 100 degrees (Centigrade), that is from about 50 above to about 50 below zero.

That highly-organized chemical compound which forms the physical basis of life, which we call protoplasm and which is highly albuminous in its nature, coagulates like the white of an egg when subjected to a temperature far below 50 degrees (Centigrade) and freezes if the temperature falls much below zero or the freezing point. In either case the life phenomena soon cease to manifest themselves and become impossible—life is suspended or has simply ceased to be.

It is a simple matter, therefore, to deduce from these circumstances that life could not have manifested itself on our globe until a temperature suitable to its existence had been reached. And if our planet came into being, as Astronomy teaches us it did, this could not have been until some time after it had taken its place in our solar system; for its temperature in those early days must have been much too high for life, as we now know it, to exist upon it.

Our globe, then, must once have been as lifeless as the outer planets or our sun, with their higher temperatures, are said to be.

It matters not which of the views we hold respecting the origin of our cosmos; whether it be the product of condensing, gaseous matter as the nebular theory teaches, or, as the more modern view advocates, of accretions and aggregations of meteoric bodies such as we know to be roaming through space and which are calculated to fall upon our earth at the rate of ten millions of tons per annum; in either case, on the evidence of the condition of our own sun and the outer planets, our earth was once too hot for life to exist here.

Such being the case the question now arises: Did life, then, spring spontaneously upon our globe, as some Mechanists believe, and is it confined to this earth; or did it originate elsewhere; and is it found on other bodies in space?

There questions are not so easy to determine and scientists hold different opinions concerning them.

The eminent French astronomer, Flamarion, who has made a life-long study of Mars—the planet of our system whose conditions approximate most closely to our own—does not doubt for a moment that life in some form or other has existed and still exists on Mars; and if on one body in space then why not on others?

It would seem from our knowledge of life that the question is one of conditions more than of anything else. And out of the myriads of floating spheres that exist in space some must have passed, or be passing, through those phases of evolution which are analogous or similar to those on our own sphere.

But supposing life did exist on other bodies in space have we therefore, any grounds for thinking that it must be of the same nature as life on our own; and could it be conveyed from them to us? Might they be the proximate source of our earth life?

In regard to the first question, we have learned that every life-form we know—no matter how complex or how different its form, whether it be an

elephant or a mouse, an oak-tree or an onion, a monkey or a man—begins its existence in the same way. Each starts from a tiny microscopic cell or speck of protoplasm, which in its earliest and simplest form is the same in the one as in the others, though their potentialities and forms are later to become so different.

It is not unreasonable, therefore, to conclude from this fundamental fact that life wherever found must, in its lowest terms, be the same everywhere though its fully-developed forms may vary indefinitely. Insofar, then, as the life conditions on other heavenly bodies differ from those on this earth, so may their organic forms differ from ours.

But this does not necessarily mean that life anywhere throughout our universe is different in its essential nature. In this respect it must be the same everywhere, even if it has appeared spontaneously and independently on every celestial body that contains and manifests it.

But has it so appeared spontaneously on every sphere on which it may exist? Is it necessary for us to think this? Could it not have been transported from one body to another across space? Is this possible? Could life not have come to us, for instance, from some other sphere?

Concerning these questions Helmholtz, one of our greatest scientific thinkers, reasoned thus: "It seems to me a perfectly just scientific procedure if, after the failure of all our attempts to produce organisms from lifeless matter, we put the question, whether life has a beginning at all, or whether it is not as old as matter itself; and whether seeds have not been carried from one planet to another and have developed everywhere where they have fallen on fertile soil."

And the famous Danish physicist, Arrhenius, adopting this suggestion of Helmholtz, which is known as the "Panspermia theory," has combined with it the fact of "radiant pressure" and made it appear as a reasonable and plausible hypothesis.

He takes the stand that the universe in its essence has always been what it is now; that the three great principles or entities—matter, energy and life—have through the ages only varied in their form and position in space but have never been absent from it.

Arguing thus he sets out to show on scientific grounds that this idea of Helmholtz, of seeds floating about in space and passing from one world to another, is a wholly reasonable and even probable hypothesis; and the agency he invokes to bring about this condition of things is the principle of radiant or light pressure.

It will be necessary to make a little digression here and to wander a short way into the realm of physics, in order that it may become clear how this agency could accomplish the task of transporting life-seeds through the infinite meadows of space.

Under the most widely-accepted teaching of modern science "light" consists of waves in the ether of space —waves of electric and magnetic disturbance, microscopic in length. (The "length" of a wave is the distance between the crest of one wave and the next following.)

It has been calculated that strong sun-waves, such as summer sunlight, falling perpendicularly against a black or absorbent surface, exerts a pressure of rather less than one two-hundred thousandth of a gramme on a square inch, or about two and a half pounds on a square mile. An ordinary light-wave is about one fifty thousandths of an inch long. They follow each other, therefore, very quickly. A train of waves acts like a spiral spring; they contain energy, and the more they are compressed, the more energy is put into them.

The pressure of light being relatively so small we cannot expect to detect any effects from it on the large bodies of our solar system. The whole pressure of light, for example, falling upon the earth would, if none were deflected but all absorbed, (which never happens) amount only to about 74,000 tons weight, a wholly negligible quantity when the bulk of the earth is

considered. This is calculated by taking the energy of the sunlight at the distance of our earth (some 90,000,000 of miles) as 2.5 calories per minute per square centimeter. This in comparison with the gravitational pull of the sun on the earth—a force 47 millions of millions times as great—is as nothing. Yet, notwithstanding this small pressure of radiant energy, it has a very real force of its own given the conditions proper to its action. Its efficacy or power is dependent upon the mass of the body acted upon. It increases proportionately with the diminishing size of the body; whereas the gravitational force as we know, increases in the opposite direction. It can easily be seen, then, that a time must come when these two opposing forces may just equalize each other in their action on some floating particle of matter. When this happens, and the body acted upon by these two forces falls below the balancing point in size, then the light-pressure will exceed the gravitational pull and the particle will be thrust off into space.

We may sometimes see an example of this in the movements and relative positions of a comet's tail. The tail, which is composed of infinitesimal particles of matter, is often seen to stretch out at some angle from the comet's line of motion on the side farthest from the sun; and sometimes it may be observed to be travelling ahead of the comet itself more like a flaring horn than a tail. All these strange movements are caused by the pressure of the sun's rays upon the particles composing the comet's tail.

If there are dust particles, then, in the solar system one one-hundred thousandths of a centimeter across and not much denser than water, they would thus be driven by the pressure of the sun's rays right out of our system into outer space.

Now we know that some organisms are so infinitesimal in size that they lie quite beyond the powers of our finest microscopes to discover them. We know of their existence and presence only by the effects they produce in other organisms; and as we have no grounds for limiting the smallness of a floating spore or life-germ, and our atmosphere is full of all kinds of them, given the proper conditions it might easily become subjected to radiant pressure and be carried anywhere throughout space.

In this way life might conceivably have reached our globe from some other body and have found lodgement here when its surface-heat had fallen low enough for life-germs to maintain their existence. This maximum, as we have seen is about 85 degrees Centigrade scale or about 185 degrees Fahrenheit, that is 27 degrees below boiling point.

We know of only one organism that can withstand so high a temperature and carry on its functions. This is a species of alga, one of the lowliest and simplest of our life-forms, and probably a descendant of one of the earliest that existed in the dawn-days of earth-life.

This organism seems to thrive best in some of our hot springs where the temperature rises as high as 85 degrees Centigrade. We know of no other living form that can survive for any length of time in such a temperature and under such conditions.

It is true the spores or germs of certain bacteria will withstand temperatures exceeding 100 degrees Centigrade; but that is because the albumin in the spore is very dry and is encased in a highly-resistant covering or shell which is able to withstand for some time the action of the heat upon its contents. But no functioning organism could undergo such temperatures and continue to exist.

Granting, then, the plausibility of the Panspermia theory; and that life-germs in the form of spores may thus be transported across space from one body to another by radiant pressure—and as we have said, their size would not seem to preclude this possibility, for we know of spores of microscopic bacteria less than 3|2,500ths of a millimeter in length and half this in width; therefore the spores of the ultra-microscopic organisms could scarcely, if at all, exceed

the size of those particles of matter that fall under the influence of radiant pressure—we have but to find an answer to the further question: Can a life-germ thus transported maintain its life or germinating power on its long journey without injury from the sun's rays or from the cold of interplanetary space?

Arrhenius thinks that an affrmative answer may be given to these questions. He says botanists are generally of the opinion that it cannot be killed by light rays in their wanderings through infinite space. And as for the effects of cold it has been proved at the Jenner Institute in London that some spores will maintain their germinating power after being kept in liquid hydrogen at a temperature of minus 252 degrees C. And Prof. Macfadyen has shown that certain micro-organisms may be kept in liquid air at a temperature of minus 200 degrees C. for six months without destroying their germinating power.

As far then as the cold of interplanetary space is concerned the Panspermia theory encounters no insuperable difficulties in this direction; rather, indeed, does the low temperature of space facilitate and make possible the transference of life-germs from one part of space to another., without serious deterioration or loss of germinating power.

In the same way it is claimed that the known destructive effects of sunlight upon certain micro-organism would be minimized in interplanetary space by its greater feebleness there. These spaces are also absolutely dry and this would have a favorable effect, too, upon the life of the germ.

Granting, then, such a transportation of life-germs as the Panspermia theory postulates—which the fact of light-pressure or radiant energy seems to make possible—it would appear to be quite within the bounds of possibility for a life-germ to have reached our earth in its early history and to have given rise, under the working of those biological laws we considered in the second chapter, to the varied life-forms which have since appeared here.

We have the choice, therefore, of the two views respecting the advent of life on our globe. We may prefer to think of life as appearing on this earth directly from its primal source wherever and whatever that may be; or we may hold with Arrhenius that it has probably come to us from some intermediate source such as some other planetary body in space.

According to him life may have been transported in this manner for eternal ages from solar system to solar system. If this should be so, then it follows as a natural corollary that all organic beings throughout the whole universe are related to one another and would therefore, like ourselves and the other life-forms on the globe, consist of cells built up like our own chiefly of carbon, hydrogen, oxygen and nitrogen. Life, therefore, on the other planets that are in a condition to harbor and support it, has probably developed, he thinks, along lines similar to those on our own globe, just as every individual organism here has in its own life-course passed through and recapitulated, however briefly and slightly, the decisive or crucial stages of evolution, taken by its ancestors from the single cell stage up to its own many-celled form.

The acceptance of either of these views does not, of course, settle what is to some the greatest question of all—the question of the ultimate source of life. But those who would find an answer to this question must seek it apart from science. It is one into the consideration of which from its very nature science cannot enter. That is the province of Metaphysics.

We may bring this chapter to a close by pointing out that our consideration of the origin of life on our globe has brought nothing to light that in any way makes the doctrine of organic evolution impossible to hold—rather has it given support thereto. In the next chapter we will consider briefly the age of our globe and thus incidentally also learn something of the age and first appearance of the life-germs upon it.

CHAPTER V.

When Did Life First Appear on Our Globe?

IN the last chapter we considered the question of life from the point of view of its origin and source. and sought to determine whether it first manifested itself here on this globe or whether it came to us by way of some other celestial body; and could only reach the conclusion that one might consistently hold either view as far as the facts of science were concerned; though the probabilities, in the light of the Panspermia theory, seemed to favor the latter view.

We can at any rate be sure of one thing which ever view we may take, and that is that life must have first manifested itself under the simplest and most primitive forms; and that these were probably ultra-microscopic in character.

It is certain that such organisms only, as we saw in the last chapter, could have reached us from outside our globe through the agency of radiant-pressure; and the fact that we find such life-forms on our globe today would seem to suggest that even if life first arose here it must have been under forms of this kind; for they are the simplest and least complex of which we have any knowledge; and it is only reasonable to suppose that life in its earliest was also in its simplest stages.

Indeed, when we come to consider the life-forms themselves we shall find that the functions and activities of the lower forms of life are so indispensable to the existence of the higher and more complex ones, that we are forced to take the view that in the great chain of life the lower must have appeared earlier in time than the higher, because they are seen to be absolutely necessary in the life of the higher. This fact will become increasingly clear as we proceed in our consideration of the progress of life, and will constitute the first great link in the chain of evidence of organic evolution.

And as the question of the ascent of life is so closely associated with the element of time it will be found profitable if we devote this chapter to a consideration of the age of the earth; for only in this way shall we be able to gather any definite idea of the length of time living forms have existed upon it; and so find an answer to the question: When did life first appear on this globe?

In our consideration of the nature of life we saw that it was strictly conditioned by temperature; and that it could not have existed here until the temperature of our earth had fallen below 100 degrees Centigrade.

How long ago was this? How old is the earth?

Men of science have long sought answers to these questions. They have approached the problem from different points of view with the result that their conclusions have not always been closely concordant. In order to appreciate and compare these conclusions, and see where they lead us, let us briefly examine their modes of inquiry.

We can best do this by taking it for granted, as they do themselves, that in the beginning the earth, as the Scriptures have it, was without form and void. We may assume, further, that it was at one time in an incandescent, liquid state. Upon this point the great majority of scientific men are fairly agreed.

This super-heated condition may

have been brought about by more than one agency. But we need not here concern ourselves with the question of the mode of origin of our sun and the planetary bodies, whether they came from the condensation of nebulous matter or from the accretions and aggregations of meteoric bodies which became incandescent by having their energy of motion transformed into the energy of heat by impact upon each other under the force of gravitation, or in any other way; the one outstanding and fundamental fact is that in their earliest condition they were intensely hot masses; and so high was their temperature that the elements forming them could exist only in a volatilised or liquid state.

The sun itself and the outer planets appear to be still more or less in this condition; and that our earth was also formerly in this state and has since become cooled and solidified at its surface while its interior still remains exceedingly hot, several obvious physical facts seem to make quite clear to us.

One of these is that the deeper we penetrate into the earth's crust the higher the temperature becomes. We find that on the average it rises one degree F. for every 65 feet of descent. We have penetrated to a depth of 7529 feet and found the temperature at this point 186.6 degrees Fahrenheit; from which it would seem to follow that at a depth of about 35 miles the heat would be great enough to melt the most refractory substances; and that below this point the earth must be in a molten state with the central portions so hot that the matter there must be in a highly volatilised or gaseous condition.

We may feel reasonably sure of this; for what took place æons ago in our earth is now taking place in the larger of our planetary bodies. We may in their transformations, therefore, read the past history of our own globe.

Another obvious physical fact leading to the same conclusion may be seen in the occasional crustal movements we know as earthquakes.

These movements through the earth teach us that the hard outer shell or crust cannot be very thick, and that the core of the earth is probably gaseous.

From observations of earthquake movements Milne, one of our highest authorities in this matter, has deduced the thickness of the solid portion of the earth's crust. He finds it to be 50 kilometers or about 30 miles only.

This deduction agrees practically with the conclusion reached by Arrhenius, who, by estimating the increase in temperature in penetrating the earth's crust, found the solid portion to be about 35 miles thick.

Again, observations of the nature of volcanic actions, the up-thrust over large areas of eruptive material in the form of dikes and "trap-rock," and the presence of hot-springs in various localities, all lead to the same conclusion. Volcanic action suggests to us that our globe most probably consists of a great mass of gas which is so highly compressed as to be as rigid as if it were composed of steel. This is enclosed in a shell or case, which is solid on the outer side and on the inner remains in a plastic viscid condition.

A most interesting proof of this viscous state of things below the earth's crust, which makes it seem pretty certain that our conceptions of the earth's interior is in accordance with the actual condition of things prevailing there, is furnished by a peculiar diminution of the force of gravity in a mountainous region. And as it is supposed to be due to the fact that the specific gravity of the mountain mass is less than that of the denser molten matter of the interior, we may get some idea of what brings this phenomenon about by observing how an iceberg floats in the sea.

We must not, however, press the analogy too far as the physical conditions in the two cases are radically different. Apart from this, however, the analogy is helpful and suggestive; for something very like this submergence of the lower portion of the iceberg in the water must take place in

the depths of the earth wherever there are mountains.

This conclusion suggests itself to us by our measurements of the force of gravity in mountainous regions. In such regions, according to Wallace, this force is found to diminish not only by the amount due to the mass of the mountain above the general level of the land, but by about twice that amount.

Now this curious and interesting fact seems to have no other explanation than that the "roots" or foundation of the mountain must extend far into the magma or fluid matter of the earth's interior, just as the "roots" or submerged portion of the iceberg extends below the surface of the water, only in different proportions.

There seems to be no other way of accounting for the diminution in the force of gravity in these circumstances. The specific gravity of the mountain mass being understood to be less than that of the heavier, fluid material, we seem bound to suppose that the solid roots of the mountain masses extend far down into the liquid matter of the interior and thus lessen the gravitational force at this point.

This fact, then, of the lessening of the force of gravity in mountainous districts seems to furnish strong proof of the plastic or liquid condition of the interior of the earth's crust; for just in the same proportion as the upper part of the crust is raised up or made thicker by additions above, so must there be a corresponding thickness below to keep it in equilibrium.

From these and similar physical facts we have good grounds, then, for assuming that the earth was originally a mass of incandescent gas. In course of time by radiation into cold space, this mass of gas would gradually lose its high temperature, cool down and condense, until finally a solid crust would form on the outside of it.

Kelvin has calculated that it would not take more than 100 years before the temperature of this crust, when once formed, would sink to 100 degrees C. But even supposing he is out in his estimate by the oversight of some essential factor in the case, we could be quite sure that only a very few thousands of years at longest would elapse before the temperature would have fallen below 100 degrees C., that is below the boiling point.

From this point it would not be long before a temperature suitable to organic beings would be reached.

Accepting, then, these teachings of science respecting the origin and constitution of our earth, and admitting that life could not have appeared here before a solid crust had formed about the earth's surface, and the temperature had fallen below 100 degrees C. can we gather anything definite concerning the period when this took place? Can we learn how old the earth is and thus find out how long ago it is since life might have first appeared in organic forms or our globe?

We may certainly reach some kind of a conclusion on these points, even though it be lacking in absolute definiteness.

One method by which science has endeavored to estimate the age of the earth is to calculate it from the extent of the shrinkage our globe has undergone by contraction from cooling.

This has been estimated to be 0.8 per cent. of its radius, corresponding to a lowering of the earth's temperature more than 300 degrees C., and to effect this a period of about 2000 millions of years is said to be required.

Joly and other scientists have approached the question from a different angle, that of the age of the oceans. Let us follow their reasoning and see how they arrive at their conclusions.

Picturing the earth as having been evolved as outlined above, we may see it at one stage of its existence as a vast seething caldron, from which steam rises in dense clouds to be presently precipitated upon the hardening crust only to be again turned into clouds. Later, when the crust has thickened and the surface-heat has lessened, these vapor clouds can condense and fall upon the earth in the

form of rain. This collects and fills the hollows in the tumbled crust. These hollows or cavities, deepening by further contraction and surface movements of the crust, slowly grow into the great ocean basins of today.

But when this happened their waters were not salt as they are now. The salt of the oceans has all been derived from the crust of the earth.

By estimating the amount of salt in the sea and also in the fresh-water rivers, from which the salt of the sea has come, Joly was able to calculate the amount of salt in the sea; and comparing this with the amount that all the rivers of the world could supply in the course of a year, he was able to reach the conclusion that it would take about 100 millions of years to accumulate the present amount of salt in the sea.

This conclusion would be practically the same whether we considered the ocean basins to have come into existence in the manner described above, or whether they were formed, as some scientists now think, by the breaking away of the moon under the influence of the tidal action of the sun upon the earth's mass in its earlier and more plastic condition. It is supposed under this view that the gravitational pull of the sun resulted in giving the earth's mass a pear-shaped form; and that under the strain of the tidal action the stem-part of the earth broke away from the rest and became the moon, leaving behind great cavities in the remaining portion which became the ocean abysses we know today.

This modern view of the moon's origin explains fairly satisfactorily the presence of those abysses of the ocean which in depth are greater than the heights of the highest mountains, the existence of which has always been difficult of explanation on the ground of mere crustal contraction.

But this is by the way. We touch upon it here because it has an important bearing upon the question of the distribution of life-forms which we shall have to consider later.

Another estimate is that reached by the geologists. They have arrived at the conclusion that from 100 millions to 1000 millions of years have elapsed since the earliest sedimentary layers of the earth's crust were laid down by the rivers of archaic times. They arrive at this conclusion by observing the rate at which the new sediments are being laid down today at the mouths of our rivers and estuaries; and by assuming that the rate of such edimentations has been fairly uniform all down the ages; an assumption that s strengthened by our increasing knowledge of the secular changes our earth has passed through.

Still other estimates have been reached by the physicists. Rutherford has attempted to gauge the earth's age by estimating the age of the minerals forming its crust.

According to our present knowledge helium is produced from uranium and thorium by the slow dissociation or disintegration of these elements. Rutherford set himself the task of discovcovering how much helium comes from a given quantity of the other two substances in a year. This he succeeded in doing, and by calculating from this basis he has found that it would make the earth about 400 millions of years old.

Estimates of a similar nature arrived at by other physicists, by ascertaining the quantity of radium in the minerals of the earth's crust, give figures that differ considerably from those reached by Rutherford; some being higher and others lower than this. The examination of the archæan rocks of Ontario, for example, gave 600 millions of years as the age of the earth. Certain rocks in Norway gave only 54 millions of years. The rocks of Ceylon gave estimates running from 320 millions to 1600 millions of years; and a study of the rocks of Sweden gave figures as high as 1000 millions and 1300 millions.

Comparing these various estimates, then, we find that our globe may be somewhere between 100 millions and 2000 millions of years old.

This is admittedly a rather indefinite estimate, but when we consider that the units of geological time are mil-

lions of years, it is as near, perhaps, s we can expect to get; and by taking the mean of the various numbers given we may arrive at the fairly definite figure of about 800 millions of years.

Taking this estimate to be as close an approximation of the earth's age some form or other has existed here for at least several hundred millions of years.

Having now learned practically all we may, in the present state of scientific knowledge, of the nature and the source of life; and the length of time that has elapsed since it may have first appeared on our globe; and that this period is sufficiently long, even under the minimum estimate, for the evolutionary process, as conceived by Darwin and Wallace, to have produced all the varied forms of life now existing or which existed in the past, from a simple primordial life-germ; we are now ready to enter upon our consideration of the various lines of evidence upon which science has established the doctrine of organic evolution. And this we will proceed to do in the next chapter.

CHAPTER VI.

The Nature of the Evidence of Organic Evolution

IN THIS chapter we were to start upon our consideration of the evidence which science has gathered in support of the doctrine of organic evolution; and we cannot do this better than by first considering the nature and character of this evidence.

We find it is of two kinds—direct and indirect or inferential.

All human evidence belongs to one or other of these two classes, direct or circumstantial as it is more commonly called; and experience soon teaches us that we have to rely in far larger measure upon the latter for our decisions, judgments and conclusions than we have upon the former.

In most of the circumstances of our daily lives, and in all the events of the past, with which we have no first-hand acquaintance, and especially of the historic or distant past, we have to depend entirely upon circumstantial evidence for our knowledge of things.

By far the greater number of the criminal cases that come up in our law courts are tried out, and a verdict or judgment given, on evidence of this kind. Direct evidence on most things is scanty in comparison with indirect evidence.

We do not as a rule doubt the judgments or conclusions we arrive at on that account. We feel reasonably sure that they are in the main as cor rect and reliable as those formed from direct evidence.

By far the greater number of convictions in murder cases, for example, are based entirely upon indirect or circumstantial evidence.

And in respect of the circumstantial or inferential evidence upon which science reaches her conclusions in the case of organic evolution, and leaving out of account altogether such direct and objective evidence as we possess, it may be at once stated as an incontrovertible fact, that the circumstantial evidence which she has brought together in support of the doctrine of organic evolution is of so convincing and decisive a character, that if evidence of half its force and cogency were brought against a person charged with murder, it would assuredly hang him a dozen times over, if that were possible; he could not hope to gain acquittal.

It can truthfully be said to be the strongest and clearest evidence of a circumstantial or inferential kind human reasoning has ever built up. There is no fact so well attested in the whole realm of science as the principle or fact of organic evolution. The truth of this statement is borne witness to by the formal affirmation issued by the council of the American Association for the Advancement of Science at its annual meeting in December of 1923. Speaking upon this very subject, this is what the Council says:—

1. "The Council of the Association affirms that so far as the scientific evidences of the evolution of plants and animals and man are concerned, there is no ground whatever for the assertion that these evidences constitute a "mere guess" (as charged by Mr. W. J. Bryan in his public attack upon evolution). No **scientific generalization is more strongly supported by thoroughly tested evidences than is that of organic evolution.**

II. The Council of the Association affirms that the evidences in favor of the evolution of man are sufficient to convince every scientist of note in the world. The evidences are increasing

in number and importance every year.

III. The Council also affirms that the theory of evolution is one of the most potent of the great influences for good that have thus far entered into human experience."

This is very unequivocal, and strong language but not too strong, we think, for the occasion or the case. The many converging lines of evidence, as Bateson has remarked, point so clearly to the central fact of the origin of forms of life by an evolutionary process that we are compelled to accept this deduction.

It has been necessary to stress this fact because there seems to be a considerable amount of misapprehension in the minds of many people concerning the character of the evidence, and the authority, upon which the doctrine of organic evolution rests.

The opponents of organic evolution are for ever demanding objective proofs of the working of the evolutionary law and of the appearance of new forms. They want to be shown the process actually in operation by which, as they express it, one organism grows or passes into another of a different kind. They are not satisfied with the same kind of circumstantial or inferential evidence as they accept in other problems and in the ordinary affairs of life. They want direct and ocular demonstration.

Well, science is not without what she regards as direct, objective proof. She has gathered this as well as the indirect or circumstantial kind. We drew attention to some instances of this in a former chapter and more will be given later when we come to deal with this side of our subject.

But to take this point of view and approach the question with this attitude of mind, not only shows a strong bias and prejudice against the whole subject, but also a fundamental misconception of what the doctrine of organic evolution means and teaches us.

It ought to be readily seen by any fair-minded person that events which relate to the ascent of life from lower to higher forms, belong for the most part to a distant past, and, therefore, cannot now be observed taking place directly before our eyes.

We cannot now see our earth as a fiery mass of gas or molten matter, slowly forming a solid crust on its surface and gradually becoming the earth as we know it today; but we do not seriously question science when it tells us that this was its mode of evolution; nor do we seek to discredit its pronouncements on this head.

We accept what science teaches here because we feel its conclusions and inferences are founded upon a large body of observed facts which have no significance or meaning for us unless interpreted and related in this way.

We are satisfied that our deductions are well-founded and follow logically from the facts as far as our human understanding can grapple with them.

Why then should we ask so much more of biology than we do of astronomy? Why if we accept the inferences in the one case do we cavil at and question them in the other? They are arrived at in precisely the same way. They are logical deductions from bodies of patiently and often laboriously acquired facts.

Darwin, the founder of the doctrine of organic evolution, spent over 30 years in observing and accumulating his facts before he ventured to set forth his conclusions; and scores of industrious students of biology since his time have been adding to his body of facts until, as was stated just now, no scientific truth is more firmly established or more widely held by scientists than the doctrine of organic evolution.

We know, of course, why such prejudices have arisen in many minds against the evolutionary doctrine. It conflicts with certain inherited or acquired beliefs concerning the nature and origin of man.

According to the teaching of organic evolution, man is closely and genetically related to the other mammals. He has risen from some lower forms of life as they have. This inferential

fact is repugnant to such minds and hence their attitude towards the evolutionary doctrine. They do not seek to learn whether it is true or not; their strong prejudice against such an origin for man puts it immediately out of court for them; they will not consider it at all. But earnest seekers after truth follow whithersoever it leads them, irrespective of religious or other prejudices, or what soever cherished ideas they have to give up.

They seek to examine with open minds the evidence as presented to them; and if the facts and the reasoning in the case seem sound and good, and commend themselves to their judgments, they accept the logical inferences and results which follow, no matter what distress of mind it may for the time cause them; and seek to readjust their beliefs in accordance with the new truths they have discovered.

All fair-minded people must admit that this is the ideal attitude of mind one should at all times strive to take in questions of this kind; and this is the attitude we shall endeavor to maintain throughout these discussions.

And just here it may be well if we give a little time to the consideration of what the evolutionary process means and teaches us, and so clear away some of the misapprehensions which seem to have crept into the mind of the general reader, as well as into the minds of many of those who find themselves opposed to organic evolution, concerning the ascent of life and the passage or transformation of one organism into another. Much misunderstanding exists on this point, which makes the doctrine of organic evolution seem at times ridiculous and impossible to many people.

Let it be understood, then, in the first place that life-forms as we find them on the earth today, especially among those most familiar to us, such as the ordinary mammals, are relatively fixed and stereotyped in their characters. Radical or deep-seated changes or transformations are not, therefore, to be expected in them.

Our division of the life-forms into definite classes, orders, families, genera and species shows that the lines of their evolution have become relatively fixed and settled—or we could not thus classify and arrange them. This applies to both life kingdoms. The most we can expect to observe in our day is the appearance of new varieties of the same form; which, by continued variation or by a sudden mutation, such as we saw happened in the case of the Evening Primrose, become changed into new species.

This kind of transformation is still going on and we may see new varieties arising all the time, and some of these passing into new races and even into new systematic varieties, that is, new species.

No one who understands the evolutionary process expects the present forms of plants and animals to give rise to absolutely new kinds or forms. That is not what the doctrine of organic evolution signifies or teaches.

We shall best understand the processes and possibilities of organic evolution if we conceive of life under the simile or figure of a well-developed and many-branching tree whose limbs represent the various life divisions.

The development and branching out of this tree was largely effected in past ages. No new branches are likely to spring from its trunk while present conditions last. What might happen if these conditions were radically changed, if, to carry on our metaphor, it were perchance "pollarded," that is its main limbs severely cut back to the trunk, no one can surmise. That new branches would grow out we cannot doubt, but what forms they might take we have no means of judging. It would depend largely upon surrounding conditions and the internal forces of the tree.

We know as a matter of fact that a momentous event of this nature took place at least once in the history of organic life; and so might conceivably take place again. But these events are rare ,and they are not the usual method nature employs; and apart from the wholesale wiping out of the

higher forms of life and thus altering the equilibrium now existing in the organic world, we have no grounds for thinking any radically new forms in the higher divisions of life can or will come into being.

But what can take place, and what is taking place all the time, is the modification of the upper and later branchlets and shoots of our life-tree. These still retain some of the original plasticity and modifiability of living matter and so can respond more readily to the influences surrounding them. Their cells are nearer to the protoplasmic condition; they have not yet become fixed and set. It is in the adaptational responses we see made by the shoots and tips of the branches of our tree, that is by the present species and races and varieties of our plants and animals, to these influences, that we get some of our positive and direct proofs of the truth of the doctrine of organic evolution.

The same process which wrought all the differences in the organic world—which we have tried to systematize by separating the different forms into kingdoms, and phyla and classes and orders and families and genera and species and races and varieties, according as they resemble or differ from each other, or have near or remote relationships—is still going on, and may be perceived at work in the constant evolution and appearance of new variations from the characteristic life-forms. But because of the settled and fixed conditions and characters of these type-forms it is only such modifications and variations as these that can now arise. Strange and entirely new forms or types cannot arise in this way.

We cannot expect a horse or a cow or any other of our well-marked and specialised animals to change into, or give rise to, totally different types of animals. No evolutionist looks for or expects such transformations as these. The most he expects is what we see taking place all the time, namely, the appearance of new varieties, which, by continued modifications over many generations, or by a single leap in one generation, as sometimes happens—the evolutionary law apparently working both ways—become new races; and by still further modification, new species.

Beyond the production of new species, or possibly new genera, as the life-world is now constituted, we do not expect the evolutionary process to go.

To expect more would be to overlook and forget the law of Heredity, which works in the world of life equally with the law of Variation.

It may be recalled that in speaking of the laws of life we termed this the conservative or static principle of the life realm; and observation and experience have taught us that this stabilizing force of Heredity tends to hold well-marked and highly-differentiated life-forms, as most of the conspicuous and best-known plants and animals are today, within more or less hard and rigid lines; that it is only the simpler, more generalized forms that fall under the influence of the law of Variation and change into new forms.

We have learnt also that when environmental conditions and circumstances are stable and constant and there is no need for adaptational response on the part of the organisms, there is consequently little or no variation or change of form or function taking place.

We have knowledge of simple organisms that have an unbroken line of descent from palæozoic or very ancient times down to our own day, which have scarcely altered in form or characters through all those millions of years.

Under the working of the law of Heredity this would happen all the time but for the influence of the opposing law of Variation. And when for some reason or other, which is not always clear to us, this law fails to operate, organisms remain practically stationary and alter little through long generations.

This may be observed, by the study of fossilized life-forms, to have taken place in certain particular lines of life. The same form is passed on from gen-

eration to generation with practically no alteration; and then all of a sudden ,as it seems, something has happened in the life of these organisms and they begin to manifest an unwonted degree of variability and produce many new forms.

This may go on over a series of generations and then they seem to sink back into their old static habits and remain quiescent for another period.

The causes of these sudden or spasmodic outbursts of creative energy are rather obscure and we know little about them at present. The effects, however, seem to be much the same as those produced upon all forms of life now by the advent of spring, after the comparative quiescence of life-energy during the winter period.

That changes in the surrounding conditions of an organism may evoke responsive changes in form and function, the instances of modification we quoted in the second article—which might be supplemented by a host of other examples—make quite clear. The changes in the life conditions of the inquilines when they became the guests of the ants caused immediate and deep-seated modifications in these beetles; just as the change from a North American environment to a European one, with all that that entailed, caused an unwonted tendency to vary and produce new forms in de-Vries' Evening Primrose.

Changes, when of this adaptational nature, are clearly called forth by changes in the external conditions of the organisms. There are other changes also which have their origin within the organism as we shall see later.

Perhaps the best example in the whole realm of life of this adaptive modification on the part of organisms is seen in the results which followed the geological changes which brought the Mesozoic or middle-life period to a close and ushered in the succeeding Cainozoic or recent-life period.

In this middle-life period the dominant life-forms were the great reptiles —the dinosaurs—many of which were of colossal size and of frightful appearance.

Sharing the earth with these monstrous forms during the latter half of their period, were the earliest mammalian forms, which in the next period were to succeed them and become the dominant creatures of that period. During reptilian times these early mammals could apparently make no headway. As far as we can learn from their fossilized remains none of them seems to have exceeded a rat in size; and all were of a very generalized type, with none of the marked and highly-differentiated characters exhibited by their reptilian contemporaries.

These latter had, under the influence of the law of Variation, become so highly-specialized and fixed in their types that it became impossible for them to make the necessary adaptive response to the radical environmental changes which came in with the new geological conditions towards the close of their particular life-period; with the result that they soon apparently passed entirely out of existence and disappeared for ever from the face of the earth; their place being taken by the lowly and more generalized and, therefore, more adaptable little mammals.

From these simple, tiny, undifferentiated forms sprang by variation and adaptation, under the law of natural selection or survival of the fittest, all the highly-differentiated and specialized mammalian forms that live on the earth today, or which have since past away and left their fossil remains behind in its crust.

The lesson this fateful episode teaches us is that it is not the highly-specialized and highly-differentiated life-forms that produce new lines of life, but the simple, generalized forms which still possess the necessary plasticity and adaptive power to respond to their environmental changes. And there can be no doubt that if some great cataclysmic change overtook our globe and wiped out the great classes and orders of mammals of today, a new line of creatures would arise as in the past from the simpler

and more generalized forms that might come through the changes.

In seeking, then, for direct proofs of the evolutionary process we must always bear these facts in mind. It is not the organisms with well-marked characters and specialized forms that ever change radically, but only the simpler and more generalized ones; and these in our day all belong to the lower and unspecialized forms of life.

These are the forms Nature seems always to keep in reserve. We shall make acquaintance with some of these when we come to trace out the various links in the chain of life.

Exactly how far an organism can respond to its environmental changes will depend largely upon its degree of specialization. If this be high, as it was in the case of the majority of the great reptiles, as their fossil remains testify, then it stands little chance of survival if the changes be considerable and widespread. They are doomed to pass away and give place to less specialized and more adaptable forms.

We shall have accomplished the purpose of this chapter if in this short dissertation we have succeeded in clearing away some of the misunderstanding which has arisen in the minds of so many people regarding the evolutionary process and what is meant by it.

What has been said ought to make plain, at any rate, why we do not see new and distinct forms arising in the life-world, or the present forms changing into others quite different, under our eyes. To look for such things is to misapprehend entirely the meaning and the teaching of organic evolution.

In the next chapter we will consider the world of micro-organisms and see what may be taking place there which has evidential bearing upon our problem.

We may close this chapter with the remark that the life and activities of these wonderful specks of life furnish us with some of our strongest evidence in support of organic evolution; for here in this world of infinitesimal life-forms we may actually see and trace some of the early steps which must have been taken by those primitive forms of long ago that began the ascent of life, and made it possible for others higher in the scale to carry it on.

CHAPTER VII.

Micro-Organisms

IN THIS chapter we are to take up the study of the life-process as it is manifested in the micro-organic world.

In Chapter IV. we were led to the conclusion that no matter where life came from it must have first appeared here in its lowest and simplest forms, and that these forms must have been exceedingly minute.

It does not seem possible to escape this conclusion. It is practically forced upon us by the fact that in point of numbers the micro-organisms today constitute the larger portion of the life-world. The air, the water and particularly the soil teem with them. They are everywhere. They are about us, upon us and within us in incredible numbers. But this is not all. We have learned, too, that the higher forms of life are absolutely dependent upon some of these lower microscopic forms for their well-being and very existence.

Here, then, at the very root of the life-tree we find the strongest presumptive evidence of the truth of organic evolution; we see how closely the life-forms are related and how interdependent they have become.

Let us, then, here enter this world of primitive life-forms and see what is going on there and what lesson the activities of these minute organisms can teach us concerning the march and upward progression of life.

It is in this world of microscopic forms that some of the most amazing miracles of life take place.

In this world the mysteries of sex differentiation are first revealed to us. Here we perceive the earliest division of labor in cell-clusters which makes possible the organization of the higher and more complex life-forms.

It is in this arcanum of Nature that the Mendelian "unit characters" are segregated, assorted and recombined. Here the "dominant" and "recessive" characters are organized and fixed.

In this secret workshop of Nature, the marvel of mitosis, that splitting of the chromatin in the nucleus of the life-germ, goes on. Here are found the chromosomes, those mysterious chemical elements, that constitute the material basis of heredity.

In this laboratory of life we see the life-forms propagate themselves by fission or simple binary division, or by gemmation or budding, with such celerity that hundreds of thousands and even millions appear where twenty-four hours before there was but one.

It is a region of perpetually-occurring marvels and we could not exhaust its wonders if we discoursed upon them for a week.

We shall learn a little about some of them as we proceed in our inquiry.

We regard the cosmos as a marvel of inter-locking mechanism where mighty forces are nicely balanced and work harmoniously together. The contemplation of the structure and planetary constitution of that unit of matter we call the atom astounds us and its ceaseless, internal activity and hidden forces move us to wonder. The mighty whirling nebulæ and all the shining hosts of heaven, that lie unnumbered and unnumberable in the vast immensities of interstellar space; the ebb and flow of life as manifested in the changing seasons; and a multitude of other marvellous things, all arouse our interest and justly excite our admiration. But all these marvels of the larger world pale and sink into insignificance beside the astounding things that for the most part go on unseen in this world of micro-organisms.

Astounding as are the wonders of the atom, they are as nothing to the marvels of a life-germ.. Here in an infinitesimal speck of living substance we call protoplasm or bioplasm, may lie hidden from our vision, sleeping and quiescent, all the potentialities of such a complex being as man at his highest and best. In all the wide universe there is no marvel equal to the marvel of the life-germ. It is the marvel of marvels; and he who contemplates it in the right spirit gets such a vision of the transcendent power and wisdom displayed by the Creative Principle that he is led to bow his head in awe and wonder.

We are accustomed to regard the world of life as divided into two great divisions which we call the animal and the vegetable kingdoms. And while this method of regarding life-forms is serviceable and convenient for classification and nature studies it is far from being an ideal one. For it not only carries with it the idea of a definite separation of forms into a botanical and a zoological world, but also the implication that life has always appeared, even from the first, under these two forms, and has been thus divided into two separate, hard and fast kingdoms.

This is altogether misleading; for one of the striking things we early learn about the micro-organic world, is that no such hard and fast division of life-forms obtains there.

Indeed, biologists are disputing even yet as to which of these two life-kingdoms certain of these minute life-forms properly belong; so difficult is it to decide whether they are animals or plants.

Because of this difficulty and because of the undifferentiated character of so many of these organisms, some biologists have suggested the forming of a third or subsidiary kingdom in the life-world, which should include all the Protozoa and Protophyta, to wit, the earliest and simplest animal and vegetable forms, as collectively distinguished from the higher organisms—the Metazoa and the Metaphyta —this new division to be known as the kingdom of the Protista, the realm of the very earliest organisms.

We can, however, avoid these divisions and strange terms by employing a much simpler classification which will answer our purpose much better. Instead of dividing the life-forms into three, or even two, separate life-kingdoms we can divide them more simply on the lines of their structure.

By employing this method we find that they can all be placed in two simple classes or groups—one comprising all single-celled organisms and the other all many-celled forms.

This method does away also with the artificial division we are inclined to make between the microscopic and the visible forms of life.

To the first of our two groups belong all these forms termed by biologists protozoa and protophyta and to the second all those called metazoa and metaphyta. In this way we unite all the life-forms in both divisions into one inclusive life-realm, and thus get a clearer outlook on life as it really is.

The distinctions we have made in the life-world are purely artificial ones and have no real existence in nature itself; she recognizes none of them. Life is an unbroken and continuous stream whose flow has gone steadily on since first it left its source, gathering force and volume as it has proceeded.

It is the same stream in the world of microscopic life as in the world of larger life. The only difference being that as we retrace the course it has taken it grows narrower as we approach its source. But this is what should happen if life began, as we have seen it must have begun,, in some tiny spore or germ.

Regarding the life-realm, then, as consisting, as it does, of two groups of life-forms—unicellular on the one hand and multicellular on the other—let us see what conclusions we are led to form by the contemplation of life from this point of view; and what bearing it has upon the doctrine we are examining.

If what has just been said concerning the oneness of life be true, then a

close relation should exist between these two groups of organisms; the one should lead insensibly into the other.

Is this what takes place? Is there an intimate relation between the two groups? Is one a continuation of the other?

Here for once, at any rate, science can be very positive and give a very definite reply. We have no greater certitude upon anything in the whole realm of science than we have upon this point. Nothing is more certainly known than that the fundamental unit of life is the germ-cell; that every multicellular organism starts out on its career—whether it is to become a simple flower or a mighty red-wood tree, a lowly worm or that highest of organic forms, a human being—as a single cell. And that the only essential difference between the simple single-celled and the complex many-celled organisms is that the former carry on the functions of life singly and alone, and the latter as a group or congeries of individual cells which have all been derived from the one original germ-cell; and have become modified in their structure and function by reason of their union and associative relations in the common body.

The little mouse, the gigantic elephant and we ourselves, together with every other multicellular life-form, are each and all merely smaller or larger cell-colonies or republics made up of a greater or less number of individual cells which have become organized by the life-processes into distinct kinds or groups, each having its own specialized functions to perform. Some are nerve cells for receiving and carrying stimuli, some muscle-cells for contractibility, some gland-cells for secretion and some bone-cells for body supports. But whatever their function or purpose they still remain cells and carry on their individual life as constituent parts of the whole. They are born—each group of cells, as a rule, propagating its own kind—become mature, grow old, decay, die and are cast out of the organism, their place being taken by new ones.

If we take very thin slices of the bones, muscles or nerves of the body of an animal or of ourselves, and stain them, as we may, with different colors so as to be better able to examine their ultimate structure, we find that all the tissues of the body, whether of nerves or muscles, or bones or glands, or whatever it may be, are made up of countless numbers, that run into the billions, of separate yet interlaced and interdependent microscopic bodies. These are our individual cell-units.

This union of individual cells to form compound multicellular bodies is of two kinds. One, such as we have just described, where the union is of a permanent kind , and where the whole group or mass spring from one original germ-cell; which by subdivision of itself, by fission or by budding, gives rise to all the groups of specialized cells that together make up the organism. Colonies or associations of cells of this kind we consider, because of their permanent compound form and their closer union, are later in time than, and an evolutionary product of, the other more primary form. This other consists commonly of a group of cells of all one kind where no differentiation into special classes and no division of labor has yet taken place, but where each retains its own individuality and independence to a greater or less degree; and where the grouping into colonies has not yet reached that perfect integration and interdependence characteristic of the higher, multicellular organisms.

And, as if to make assurance doubly sure and confirm us in this assumption, the two kinds of colonies or cell-aggregations are linked together by an intermediate group, where we may perceive the earliest stages in cell differentiation and division of labor actually taking place before our eyes.

All degrees of association and union are found in the earlier and intermediate colonial groups. Indeed we can here watch the steps by

which the independent single-celled organisms passed into the many-celled forms and became the closely-integrated, complex organisms we find on the earth today, and nothing can be more instructive than to do this. No one who observes the progressive stages by which the individual cells are seen to associate themselves together into co-operative groups or colonies can have any doubt about the truth of organic evolution. We will later trace some of the more conspicuous of these stages. But let us first learn a little more about these "vital units" whose association makes possible the higher complex forms of life.

The discovery of the cellular basis of life, to wit, that every organic form, no matter how complex or how large, is composed of groups or unions of individual cells, was one of the greatest achievements of the last century

In importance in biological studies and in its illuminating power it stands second only to Darwin's great generalization—the principle of organic evolution itself and forms one of its strongest buttresses.

As can readily be seen it links all organic forms into one progressive series, uniting the higher and more complex with the lower and more simple; making one continuous, unbroken and advancing chain of forms from the humble alga plant to the stately oak-tree, or from the lowly amœba to the highest human form.

We repeat again, no one can view life with open mind and a desire for the truth and observe this grand upward march of its organic forms and remain unconvinced that "Creation" was by "Evolution;" that the doctrine of organic evolution is the most illuminating concept that has ever entered and enlightened the human understanding.

This is particularly brought out when we view this progression of life-forms in conjunction with the evolution of the embryo, in whose earliest unfolding, and development are recapitulated, as we shall later see, so many of the crucial steps and stages taken by the early multicellular organisms in their passage from the simpler to the more complex forms; the one process reinforcing and interpreting the other.

The typical vital or organic unit which we call the cell is in appearance and character a structureless speck of seemingly homogeneous protoplasm. The highest power of our microscopes reveals little more to us of the physical structure of this basis of life than does the naked eye.

Its outstanding feature is its colloidal character. To the eye it is ordinarily colorless and moderately transparent; of a glairy or sticky semifluid consistency resembling the white of an egg; sometimes with and sometimes without an inclosing membrane or containing wall, and of varying microscopic size.

Chemically considered it consists of an extremely complex and unstable combination of the elements carbon, oxygen, nitrogen and hydrogen with minor quantities of a few other substances.

We have reason, however, to believe that the apparent sameness of this protoplasmic substance is due largely to our inability to detect differentiation. All the unicellular organisms of which we have knowledge today are relatively advanced forms of life. They are not the earliest forms. They must have been preceded by much simpler forms, simple as they themselves are when contrasted with multicellular bodies. The life-germ or cell of the very earliest organisms must have been wholly undifferentiated, those we now know being all more or less differentiated. We are justified in this assumption by the varying degree of differentiation we perceive in the lowliest life-forms.

Within the speck of protoplasm forming the simplest of these cell-units are scattered certain minute bodies or granules.

These play a very important part in cell growth and evolution, especially in the typical cells where these granular bodies have been collected or segregated into a nuclear centre or dot, which is known as the nucleus. This

seems to be the most significant part of the whole cell-body, its purpose being to act as a kind of governing or controlling centre.

We may look upon the presence of this differentiated and segregated nuclear matter as constituting the first great step in organic evolution. For we have reason to believe that in the lowest forms of life the properties which in the typical cell now seem to belong to the nucleus, were characteristic of the cell-substance as a whole. This cell-substance considered apart from the granular matter within it is technically known as cytoplasm. At any rate, in the simplest unicellular organisms the differentiated granular matter is not segregated into a centre, but remains distributed irregularly throughout the whole cytoplasm.

In the higher cells, which we now commonly regard as typical cells, the nuclear substance is seen to be partly liquid and partly granular in character. To this latter, when considered as a whole, the name "chromatin" has been given because it is capable of being stained with coloring matter. These colorable bodies are the wonderful "chromosomes" that lie at the base of and constitute the material agency by which our heritable qualities and characters are passed on from one generation to another.

We shall have occasion to return to these again when we come to the consideration of the transmission of inherited or acquired characters—one of the most baffling and just now the most warmly-disputed subjects in the whole realm of biology.

In addition to the nucleus and alongside of it, is another separate body called the "centrosome." This appears to consist of a single minute granule lying in the cytoplasm, and is believed to play an essential part in the cell-division and multiplication of the typical cells.

It is the part of the cell which is concerned with that marvellous process we referred to a little while back as "mitosis." This process involves the splitting-up and division of the nuclear chromatin between the parent and daughter cells in cell-division or propagation. Later we shall observe how this remarkable thing comes to pass. It is one of the most wonderful processes in nature and is the more wonderful because it takes place in a body of microscopic dimensions.

Here we will pause for the present and continue our consideration of these unitary bodies in the next chapter.

CHAPTER VIII.

Bacteria

IN the last chapter we began our consideration of the micro-organic world and learned that the simplest and lowliest life-forms were all unicellular in structure and that the higher and more complex forms were nothing more than groups or aggregations of these simpler ones, that man himself as an organic form, was but a cluster of these—a kind of co-operative colony or republic, as it were, of individual cells—which, while retaining throughout the life of the body their own individuality, carried on their functions and normally worked harmoniously together in the interest and for the well-being of the body as a whole.

We saw also that the material basis or unit of life was the cell—a tiny microscopic speck of semi-fluid colloidal matter made up of cytoplasm and certain wonderful granular elements that played important parts in cell-division and in heredity.

In this and the following chapter we will seek to learn something of the different kinds of unicellular organisms and mark their progressive advance from the very simple to the less simple and from these again to the earliest stages of multicellular organization.

The simplest and earliest of unicellular life-forms known to us to-day are according to the opinion of many biologists, the bacteria, of which there are many kinds. Migula, one of our high authorities on bacterial life, enumerates no less than 1272 distinct species.

Formerly there was much discussion among biologists whether the bacterial organisms should be classed as plants or animals as they exhibit in themselves the characteristics of both life-forms.

It is from this lack of differentiation, in respect of these distinguishing traits, among the lowest organisms, and especially among the bacteria, that we are led to conclude that in the most primitive life-forms there was no distinction between plant and animal forms, the traits which now distinguish them being then manifested in one and the same organism.

Thus, for example, their freedom of movement, their general method of locomotion and other animal peculiarities suggest the activities of the protozoan. Notwithstanding this they are now generally regarded as plants because of their manner of reproduction, which follows more closely the methods of the earliest plants, and because of the ability displayed by the most primitive forms among them to obtain their food directly from inorganic substances; this latter power being the outstanding characteristic of the plant-forms of life; the animal-forms being dependent upon organic substances for their food, and, therefore, upon the vegetative forms which manufacture these for them.

From whatever point of view we regard bacteria they are obviously a very heterogeneous or dissimilar group of organisms. They have clearly been subjected to much variation. Their genetic relations are difficult to determine, some species suggesting relationship with some of the groups of the fungi—lowly life-forms that like the bacteria belong to the very primitive organisms—others again seem more nearly related to that large and heterogeneous division of early plant life, the algæ; and especially to that group among them which has the most primitive characters—

the blue-green algæ, as they commonly are called.

Most of the bacteria are extremely minute, some indeed, being ultra-microscopic in dimensions and lie quite beyond the range of our most powerful microscopes. The characters of these are necessarily unknown to us and we know of their existence only by the baneful effects some of them have upon the larger organisms.

One of these forms is the bacterium of yellow fever, another is that of measles, and still another is that which is just now causing such severe losses and so much worry to the stockmen of California, the bacterium which is responsible for that troublesome scourge—the foot-and-mouth disease. All three of these bacteria are too small for detection or isolation which makes it difficult for us to get control of them and lessen their activities. It is estimated that the monetary loss alone which the latter is causing the people of California at the present time amounts to a million of dollars daily.

Happily for humanity and the higher organisms generally the vast majority of bacterial forms render us useful and beneficient services. Indeed, without the activities of some of them life itself would not be possible for many organisms, especially for the higher ones; and in the early days of life on our globe they played a large and important part in making it habitable for more advanced forms.

Only a few species are harmful to humanity. These are known to medical science as pathogenic or disease-inducing bacteria. Most of these have already been brought under control by means of anti-serums which when injected into the blood of an animal give rise to conditions which make it possible for the animal to become more or less immune to their attacks.

Bacteria are of different shapes as well as of different dimensions. Speaking generally there are three well-marked forms, namely, the rod-like bacterium known to bacteriologists as the "Bacillus," the curved or spiral form called the "Spirillum," and the spherical form termed the "Coccus."

The largest known bacteria are about 1|20 of a millimeter in length and 1|200 in width. The smaller kinds range from 1|200 of a millimeter to the limits of microscopic vision and beyond. (A millimeter is about 1|25 of an inch).

Some species of bacteria—notably the bacilli of diphtheria—exhibit a considerable amount of variation; from which it becomes clear that the law of variation is as actively at work in the microscopic world as in the world of visible forms; and that if we could trace all the stages taken by the bacteria in their earlier life-history we might discover the links which relate them to the other primary life-forms such as the fungi and the algæ.

Their diminutive size prevents us from learning much about their internal structure. We know they are among the simplest of the primitive life-forms and many biologists regard them as being the very simplest and lowest organisms on the globe to-day. We know they have not reached the stage of evolution characteristic of the typical cell. Their chromatin has not been segregated or localized into a nuclear body; they have no distinct nucleus. This essential part of the higher, typical cell is represented in them by certain scattered granules; from which we may fairly conclude that in the earliest and simplest cells or life-forms the nuclear matter was not localized as it is in the nucleus of the more advanced forms; thus clearly showing that this segregation of the chromatin into a nuclear body was one of the early steps in organic evolution.

Unlike a genuine plant many of them possess powers of locomotion which resemble those of the primitive animal forms. To their cell-walls are attached cilia or hair-like filaments by the movements of which they propel themselves along; and relatively

to their size they move with considerable rapidity. The bacillus of typhoid is estimated to travel 2000 times its own length in an hour and the spirillum of cholera has been known to go 45 times faster than this.

Comparing their speed of travel with that of a large animal it would be equivalent to that of a horse when trotting.

Their usual method of reproduction is by binary division; that is to say each little sphere or rod or spiral, after elongating itself, divides into two segments, each of which soon increases to the original size to again divide into two parts. This multiplication of forms goes on continuously and very rapidly under favorable circumstances, so that in a short time incredible numbers are produced. In 24 hours one of the most prolific kind could multiply itself, if all the new forms lived, into many millions of millions. One of the outstanding facts about the lowlier life-forms is the prodigality with which they reproduce themselves. Life in these lower forms is exceedingly insurgent and exuberant. This applies to the visible as well as to the microscopic life-forms.

Certain bacteria have a secondary method of propagating themselves by means of spores. Instead of dividing themselves in the normal way by fission their cytoplasm becomes broken up within the cell into a larger or smaller number—sometimes only one —of spore-like bodies. These are known as endospores. The purpose of this secondary method, which is apparently a return to an earlier method of reproduction, seems to be to enable the bacterium to withstand unfavorable conditions of life. In this spore or germ state it possesses astonishing powers of resistance to cold and heat and desiccation; remaining quiescent and retaining its germinating power over long periods of time. We saw in a former chapter that certain bacterial spores could withstand temperatures above the boiling point and also retain their germinating power after being kept for months in liquid air at a temperature of minus 240 degrees. This is because in the spore state the enclosing membrane is sometimes relatively very thick exhibiting a shell or strata-like condition.

Remembering the possibility of life having come to our globe, as we saw in the 4th chapter, from some other planetary body in space, and also, that if this were so it could have come only in the form of a spore-germ, we may justly conclude from this habit of occasional spore reproduction among the bacteria that reproduction by spores was very probably the earliest method; and as it is not now the normal method of reproduction among them, the normal method by binary fission would thus mark a distinctive step upwards and one of the earliest advances in organic evolution.

It is probably in the manner of obtaining and assimilating their food that the highest degree of differentiation among these primitive life-forms is most plainly manifested. They exhibit in this respect all the phases of metabolism, that is the processes of nutrition and growth, peculiar to both plants and animals. It was largely because of their possessing these general powers of securing and utilizing food elements that biologists found so much difficulty in deciding whether they should be classed as plants or animals.

Some bacteria, like the ordinary green plants, require neither organic carbon nor organic nitrogen as do all true animal forms. They are able to build up both carbohydrates and protein out of the carbonic acid gas of the atmosphere and from the inorganic salts, directly. These are the most primitive kind and in this respect they exhibit traits which are characteristically plant-like. Among these are the kinds which are so useful and essential to other life-forms.

Other species of bacteria are quite unable to do this, and need carbon in organic forms and nitrogenous compounds like the animals and ourselves. These have made the greatest advance

in the ascent of life and thus link the two life realms together.

There is still a third kind which have also lost the ability to any longer manufacture their own food from the inorganic substances and which are now wholly parasitic in their habits and exist only in the tissues of other organisms. These latter absorb their food directly through their cell walls and this food is as varied as their habitat. They also display animal-like traits inasmuch as they cannot any longer obtain their own food directly from inorganic substances.

Of all the characteristics of the bacteria one of the most remarkable and, to us, the most significant is their occasional passage into what seems to be a resting state. When in this condition they are known as "zoogloeae" As zoogloeae they become temporary multicellular bodies or colonies of various shapes. We know them best under the name "Mother-of-vinegar."

The simplest of these colonies are filamentous or hair-like in form the filaments being either straight or curved and of varying lengths. Other groups assume more solid forms, some being plate-like, others spherical or ovoid or reticular or branch-like in form. When the resting period is over these groups break up again into unitary bodies and each cell or bacterium carries on its own individual existence in the usual way.

These groups or colonies are formed by the active division of one or more mother cells. They remain in this colonial form for a shorter or longer time according to circumstances. Some of these groups of cells are several inches across and so must contain countless numbers of individual cells, the whole zoogloea, as its name implies, being glued together into a gelatinous mass.

Exactly what purpose this so-called "resting-stage," this grouping of cells into colonies, serves in the life of the bacteria is not clearly known. There can be no doubt however, that the individual cells derive some benefit from this association or it would not take place. We can feel sure of this. It is not a condition of things peculiar to the bacteria either. A similar phenomenon is observed among the lower algæ. Whatever its purpose may be it is an interesting process to us because in it we see the very earliest evolutionary step taken by the simple unicellular organisms towards the higher multicellular life-forms. We get our first glimpse of the method by which simple life-forms become transformed into compound forms. Later when we come to consider the fungi and the algæ we shall see how the next steps were taken and how each step took the unicellular organisms progressively nearer to the multicellular forms until they become merged into, and one with, them. The evidence is all there and wonderfully complete.

This brief sketch of these lowly microscopic organisms reveals to us the fact that their life-history abounds with evidence which strongly supports the doctrine of organic evolution; and as they form the very lowest links in the chain of life it is especially important that this evidence should be clearly brought out.

Before, then, passing on to the consideration of other microscopic forms let us here briefly recapitulate and summarize the chief points of this evidence in order that we may the better realize its force.

That bacteria come under the influence of the law of variation is made abundantly clear by the fact of their heterogeneity, their wide dissimilarity in form. Not only are they divided into distinct groups by radical differences in shape and function but also into more than a thousand different species. And from the fact that within these species there exists a bewildering number of varieties it is clear that the law of variation is still actively at work among them.

From these facts alone we are bound to conclude that in earlier days fewer varieties and still fewer species must have existed; from which conclusion it is a fair deduction to say that at the very beginning of life on our globe there may have been but

one original parental form from which all the other and later ones have been derived.

This deduction appears the more reasonable when we remember their spore-bearing habits and the possibility that the primal life-form was of this nature, must, indeed, have been of this nature, if it did not actually originate here but came to our earth from some other sphere as Arrhenius has shown was quite possible.

That the bacteria are extremely primitive organisms is made clear from many lines of evidence; and if they do not actually constitute the very earliest life-forms, as many biologists think they do, they are at any rate closely related to those that do. Their life history is a very long one. They go back to the palæozoic or earliest life-period. We find them as fossils in the Carboniferous and Devonian rocks in large numbers and they would seem to have existed much earlier than this. They have an unbroken line of descent stretching back over a period that can only be measured by scores of millions of years. Few if any organisms have a longer pedigree. They are also ubiquitous. Their distribution is as wide as the world itself. They are found everywhere, another fact making for their antiquity, and for their extraordinary powers of adaptation; for they can exist and thrive not only where any other organism can but also under conditions impossible for any other form of life.

Even if it should later be shown that they are derived either from the fungi, through the yeast plants, or from the blue-green algæ, it would be a matter of small moment; the evolutionary evidence would only be the stronger. All three forms collectively represent the very simplest kinds of organisms and they might easily be collateral descendents of a common, primal, ancestral form. Each group has more or less relational contact with the others through one or other of its sub-divisions.

Another feature about bacteria, which has strong evidential bearing upon our doctrine is the fact that in the bacterial cell segregation or localization of the chromatin or granular matter has not yet taken place. This shows that the bacteria are very primitive forms and at the same time makes clear to us that the differentiated nuclear condition of the typical cell is a secondary stage in its life-history, and must, therefore, be a product of the evolutionary process. It is clearly something later in time than the undifferentiated cell. It is an important step onwards in the ascent of life.

These same traits of primitiveness and evolutionary advance are shown in their lack of definite characters. As a group they are neither truly plants nor truly animals. In their extreme divisions they combine the characters of both organisms. But in such a way that it becomes clear that the earliest and most primitive forms are those which possess the plant-like traits and the later and more complex, and, therefore, the more advanced forms, the ones that exhibit animal-like characters.

The life-history, then, of these bacterial forms, presents us from first to last with many signal proofs of evolution.

The strong differences between the higher and the lower forms, their many species and varieties, their wide differentiation in form and function, all proclaim the existence of an active evolutionary process. As Father Wasmann said of his modified beetles in the second chapter, they can be satisfactorily explained only in terms of organic evolution.

CHAPTER IX.

Fungi

IN the last chapter we devoted our attention to that interesting group of primitive organisms, the bacteria. We found that if they did not actually represent the lowliest and earliest organic forms, they must be closely and genetically related to those that did; because in their simplest and lowest divisions no differentiation into distinct plant and animal forms had yet taken place; their chromatin had not been segregated into a nucleus as in typical cells; and also because their structure was wholly of the simple one-celled kind.

We saw, too, that their life-history was full of the clearest kind of evidence of the evolutionary process; and that their wide differences in form and function and modes of life could only be satisfactorily explained in terms of organic evolution.

In this chapter we are to take up some of the other lowly forms of life, which are more or less closely related to the bacteria, and see what evidence they have to offer along the same lines.

We will first seek to discover what may be of interest in the life-history of that extensive and widely-differentiated class of organism known collectively as the Fungi. In this class are included the moulds and yeast plants, both of which play important parts in several of our domestic industries.

The Fungi are a very large group and are divided into many families, genera, species and varieties; which fact alone proclaims here at the start that the law of variation has been exceedingly active among them. Our knowledge of them is not yet comprehensive enough to estimate with any exactitude the number of species that have arisen among them. These have been variously reckoned as running from 30,000 to 150,000, and it is pretty certain that there are at least 50,000 distinct species.

This discrepancy in numbering the species arises from the fact that in the higher estimates certain distinctive races and varieties have obviously been classed as species. The criteria employed for distinguishing between the one and the other are not always the same. Hence differences may easily arise. Some naturalists regard a specimen from the purely morphological or "form" point of view, others rather from a physiological or "functional" viewpoint. Even at best when the same standards of comparison are used it is oftimes difficult to establish definite lines of demarcation between the three divisions of varieties, races and species; which incidentally shows us how insensibly a variety or a race may sometimes merge into a true species.

Later, when we come to the classification of life-forms we shall have to take up this question of what constitutes a true species, and we shall then see how difficult it is to reach a definition which is at once satisfactory to zoologists and botanists alike,: and which covers all the requirements of classification.

In the meantime we may note that naturalists are constantly at odds in attempting to classify particular specimens of any group of organisms with which they may be dealing; which fact in itself offers strong presumptive proof that species may and do arise from races or varieties by continued modifications and changes under the law of variation and in response, to environmental influences; and that is all we need consider at this point.

That the Fungi belong to the primitive organisms is clearly shown by their relatively simple structure as well as by their known antiquity and world-wide distribution.

Like the bacteria, to which some of their divisions would seem to be allied, their life-history extends far back into the distant past. We find their ancient forms in fossilized woods and in amber, and we can trace them back to the Carboniferous Period. Their relatively advanced organization in these early forms suggests, however, that they were in existence at a much earlier period than this.

The whole group of the Fungi with its many thousands of different species is now very generally regarded by naturalists as having been derived originally from the algæ. Indeed, the similarity in the morphological characters of one sub-group of them has caused it to be named the alga-fungi.

Notwithstanding the fact that they are probably derivative forms, we will here consider their life-history in advance of the algæ because, like the bacteria, they are not typical plants. They have become highly modified and differentiated, and now constitute a distinct and separate group of organisms. They have left the line of direct evolution and have strayed into by-paths of their own and have thus acquired characters and modes of living and reproduction quite distinct from that of typical plants; and they also offer us evidence upon the evolution of characters and organs not so clearly found elsewhere. They also in many ways form a natural link between the bacteria and the algæ.

Thus, they resemble the higher bacteria in their inability to obtain their food directly from inorganic substances as do the typical plants.

They appear to have lost their chlorophyll—that green coloring matter which is the essential agent in the process of assimilation in plants, and which enables them to decompose carbonic acid gas and water under the action of the sunlight, and convert them into starch and other carbon compounds.

They are now colorless or else possess only such pigments as are unable to utilize the sunlight, and, as a consequence, they have become wholly dependent for their food supply upon materials built up by other plants. They are now either parasitic or saprophytic in their habits; that is, they either live upon other living plants (or animals), or else upon the remains of dead ones.

Another interesting fact about the Fungi is that they bridge the gap between the microscopic world and the world of larger life and link them together by natural gradations. They are members of both worlds.

The common mushroom, toadstool, puff-balls, and that delicacy so dear to the hearts of gourmets, known as "truffles," and a host of other well-known forms, are all members of this group; and some of them at times attain considerable dimensions. On the other hand some of the yeast and mould plants fall below the range of normal vision and belong to the microscopic world.

This is a point of interest for the evolutionist because it demonstrates the oneness of life, and shows how the two life-worlds merge insensibly into one another.

The Fungi, too, are purely vegetable forms of life. There is not the same difficulty in classifying them as we saw existed in the case of the bacteria and which exists also in the case of the algæ, because of their mixed animal and plant characters. They may seem less interesting on that account, but they make up for it in a variety of other ways.

Within their group are included both unicellular and multicellular forms of life. The passage or transition from the single simple-celled forms to the compound many-celled forms such as we saw foreshadowed in the zoogloeae or gelatinous masses of the bacteria, has here definitely taken place. For the simple fungi are all unicellular organisms, while the higher compound forms are all

equally multicellular and are either composed of more or less complex wefted sheets of cells or else of tissue-like masses formed by the union of a number of these. That these latter are true multicellular compound bodies is shown by the fact that they attain considerable dimensions as in the mushrooms, and even undergo cell-division in their interiors, such as is characteristic of the higher organisms, which results in the development of true tissues. Their spores, too, may be either unicellular or multicellular, so that there can be no doubt on this head.

The importance of this fact cannot be overestimated in our consideration of the evidence this group of primitive plants offers of the truth of the principle of organic evolution.

It shows us again from another viewpoint the oneness of life; that life is, as we have remarked before, an unbroken and continuous chain which links up simple and compound, earlier and later, life-forms into a single and united whole.

In both the Fungi and the Algæ groups of organisms we find numerous examples of this truth. Taken together, the two groups show us how this is brought about and by what gradual and transitionary steps it comes to pass.

Let us first observe some of these as they are presented to us among the Fungi. Later we shall come upon other examples among the Algæ. For in these processes we are actually viewing some of the mechanisms or means by which the directive principle, that seems to lie behind the evolutionary process, has attained some of its ends.

In the vegetable kingdom we find much the same distinctions of form and structure as in the animal kingdom. In the former the lowest forms of plant-life are known as "Thallophytes."

Both Fungi and Algæ belong to this class. A thallophyte is a plant which has no separate and distinct root or stem or leaves in the ordinary sense of those terms. It consists normally of a wholly undifferentiated "thallus" or organless body. It represents, therefore, the earliest and simplest plant-forms we know.

They are interesting to the evolutionist chiefly in the fact that they are able to show the first differentiation of separate parts or organs in the primitive thallus, and the origin and earliest expression of sex differences and sex organs. It is from the study of these lowly life-forms that we draw some of the clearest and strongest evidence of the truth of organic evolution.

Thus we may, for example, observe among these thallophytes the first appearance of distinct external organs in the root-like processes known as "hold-fasts." The best instances of these are perhaps seen among the algæ or sea-weeds; where the "weed" is often found clinging to a rock or stone by its root-like "hold-fasts." But they may be seen also at the base of a mushroom or toad-stool or other fungus.

To the casual observer they may seem to be real roots, but they are only the foreshadowings of the true root; they are merely modified extensions or processes of the thallus itself, not a real root. These do not appear till much later in the evolutionary history of plant-life.

We also find the widest differences in individual form among the fungi. They start from the very simplest unicellular bodies, in which there exists no apparant distinction of parts, and ascend by numberless transitions or stages to more and more complex multicellular forms in which true tissues appear; and continue to advance from this point till we find them acquiring and exhibiting some of the features of the higher plants; to wit, true vessels and compact tissue-bodies, such as characterize the higher of the present-day plant forms.

When we come to consider the primitive forms of animal-life we shall find that this progression or ascent of life is exactly paralleled among them.

Speaking generally, the fungi show a decided advance in complexity of structure upon the bacteria. Besides their compound forms and their development of cellulose, tissues and vessels, their cell contents appear to resemble those of other vegetable forms with the exception of chlorophyll, and what is more important, all seem to possess nuclei. Even the isolated cells of the simpler yeast plants have each a nucleus.

In all these characters they show a definite, measurable, evolutionary advance upon the more simple and primitive bacteria. They stand higher in the scale of life, and in the multiplicity of their forms exhibit an adaptability as wide as the world itself, as might be expected of such primitive organisms. Probably nowhere in nature, does the law of variation manifest itself so plainly and actively as among them.

During their long life-history many species of them have become highly specialized both in form and function.

In one species alone there are known to be six races each of which has acquired a special habitat or mode of living, apart from which it can now no longer thrive or even exist.

This habitat is formed by a very narrow range of grasses. One of these specialized fungi will grow and thrive on barley and rye only, and not on wheat or oats or other grasses. Another will grow only on wheat, barley, rye and oats, but on none of the other grasses. Another will grow on oats and some other grasses only but not on any of the other cereals; and still another will thrive upon any of the grasses except the four cereals.

There are many other instances of this high specialization among the fungi. Perhaps one of the most interesting is that of the fungus which long ago entered into a close and intimate partnership with one of the simpler algæ. The two together now conjointly constitute that simple organism known as the lichen.

This is a case of what biologists call "symbiosis" or life-union, where the two plants have become so closely and intimately integrated as to form a single organism. This kind of union is for mutual benefit; one partner supplying the inorganic materials of their food and the other the organic elements. The organic world presents us with many instances of this kind of life-union. There are many interesting cases among the bacteria.

One is here reminded of the observation made by Father Wasmann on his parasitic beetles. We cannot supply a scientific explanation of the mode of life of organisms such as these we have just referred to, by merely declaring they were created expressly for this or that variety of grass.

The principle of evolution is the only one which gives us a natural and reasonable explanation of these phenomena. Why, therefore, should we not frankly accept it?

But it is in their methods of reproduction that the fungi furnish us with the best and most decisive proofs of the evolutionary process. Here they are particularly instructive and illuminating; for they exhibit a surprising number of methods by which life is passed on from one generation to another. They begin with the very simplest and earliest known methods and continue through a series of advancing stages until they reach and exhibit some of the relatively complex modes of fertilization found among the lower flowering plants.

As the simple single-celled bacteria foreshadowed in their temporary colonial groupings the compound many-celled forms that were to succeed them, so among the various species of fungi do we find foreshadowings of the processes and functions of reproduction that were later to characterize the higher organisms.

The yeasts and moulds exhibit the simplest methods or reproduction. Almost all of them reproduce themselves asexually as it is termed, that is without fusion or admixture of differentiated sex elements, such as

characterize reproduction among the higher organisms.

It seems difficult to determine which method preceded the others, whether budding, sporation or fission. All three methods are clearly primitive processes and all three are found among the yeasts. The bacteria exhibited two only it may be recalled—that by fission and by spores.

Some yeast plants follow the budding method of propagation. Budding consists in the formation of a new individual by the protrusion or swelling up of a part of the parent-body. The bud or new form may remain indefinitely attached to the parent by a narrow neck-like connection or it may quickly detach itself and become a separate and independent organism.

Other yeast plants have chosen to reproduce themselves by means of fission.

Fission is the automatic division of a cell or an independent organism into new cells or new organisms. Each cell or body, usually after elongation, divides itself into two segments each of which increases to the usual size and in its turn again divides into two parts. And thus the division goes on by a process of geometrical progression or multiplication until conditions hinder further reproduction, or the activity of the organisms has exhausted itself for the time being.

Yet other of the yeast plants carry on reproduction by means of spore formation. This is also the method of many of the other species of fungi; and not the least of the interesting features about this method of propagation are the diverse ways by which it is brought about.

Physiologically speaking, any cell or group of cells, separated from the rest of the organism and capable of growing into a new fungus, is a spore. Considered from the morphological or point of view of 'form," spores exhibit a wide difference in size and color; also in their method of originating and in many other ways; all of which show the influence of the evolutionary process. The only feature they share in common is their power of germination.

They may arise asexually as the endospores among the bacteria. This seems to be the earliest and simplest method. In this instance the cell-protoplasm merely breaks up into a larger or smaller number of tiny bodies. These are the spores.

The stage next beyond this is where the spores arise from the hyphæ or thread-like filaments that together make up the mass or body of the fungus, either along their course (the earlier, more primitive way) or from their points or apices (a later and more advanced method).

These may be either quiescent, vegetable bodies called conidia, or motile animal-like bodies called zoospores, because they move about by means of cilia like some of the minute primitive animal-forms of life. In the dual, undifferentiated characters of these zoospores, we may see a reversion to an ancestral type, a return to an earlier and more primitive condition; to a time when the earliest life-forms had not yet been differentiated into distinct vegetable and animal forms.

This is interesting in itself as an illustration of the biogenetic law which teaches us that embryos (and a spore or seed is a plant in the embryo form) always manifest in their earlier phases of development ancestral characters. It also makes it perfectly clear that the mature forms of fungi are evolutionary advances upon simpler ancestral forms.

Spores may arise from the union or fusion of two cells. These, in the earliest unions of this kind have not yet undergone differentation into distinct male and female cells.

These cells exhibit the earliest stages of sexuel differentiation. They have taken the first step in this direction; for while they have not yet acquired true sexual characters they foreshadow them in the fact that they differ in their nature. In other species of fungi we find the next step has been reached and though distinct sexual organs have not yet been evolved the fusing or

conjugating cells have reached the sexual stage; one is male and the other is female. The latter is dis-distinguished from the former by a greater luxuriance of growth; it is much larger. Among these primitive organisms the earliest external differentiation of sex is seen in a difference in size. The female cell is usually much larger than the male cell. In the higher organisms this difference in size is still more pronounced. The female germ-cell or ovum is sometimes many thousands times bigger than the male germ-cell or spermatozoon.

One of the next definite steps is the appearance of sex organs. Here again we find gradations in the evolutionary process. The simplest organisms of this kind are those in which only a female organ appears, namely the oogonium or spore-bearing receptacle; or if the male organ is present it is only imperfectly developed and does not function.

In these organisms the nuclei, or what seem to be nuclei, in the female cells fuse in pairs and this fusion gives rise to new spores..

In other more advanced species both sex organs are fully developed and both function—the oogonium of the female and the antheridium of the male. The latter organ is the forerunner of the anther, an essential portion of the male organ or stamen of the higher flowering plants.

With the evolution of these organs reproduction has become truly sexual and the resulting spores arise from the fusion of the sexual elements. True sexual differentiation with distinct sex organs has now taken place.

But mark how gradual and how transitional has been the evolution. It does not seem possible to observe these steps and stages and satisfactorily explain them apart from the principle of organic evolution.

Among these fungi we actually see the evolutionary process at work, going forward step by step from simple reproduction by budding to propagation by means of seed-like elements of the parent body.

First the spores or seeds are produced asexually, arising from a parent-form, which within itself possesses, more or less potentially, the characteristics of both sexes.

These in certain of the compound fungi arise from a stem-like portion or outgrowth of the organism, thus foreshadowing the stemmed flower and seed pods of the higher plants.

Next we see the earliest signs of sexual differentiation appearing. The nuclei of two different cells fuse together to form new spores. Later on these fusing cells have acquired distinct sexual charaters of a female type. Two female cells now fuse together and new spores are produced. Still later we find a male cell arising and the two sexes are now fully differentiated and stand apart. Reproduction is now by means of the union or conjugation of male and female cells or elements.

Thus we are able to see the very stages and mark the evolutionary steps by which the early vegetable organisms reached the sexual reproductive methods which in a still more perfect manner are exhibited by the flowering plants of today.

If these transitionary phases are not evidences of organic evolution then they appear meaningless and without natural explanation. But if they are regarded in the light of the doctrine of organic evolution, as we think they should be, then they have a perfectly reasonable explanation and may be looked upon as not the least cogent part of that large body of cumulative evidence upon which science has established this illuminating doctrine.

The evolution of sex has such a tremendous importance in its bearing upon organic evolution, and is so full of deep interest and meaning, that we think it desirable to devote the next chapter to a consideration of some of its most significant features and its apparent purpose in the life-realm. It will make clearer many of the arguments to follow later.

CHAPTER X.

Reproduction, Regeneration and Rejuvenation

IN the last chapter dealing with those primitive and peculiar life-forms collectively known to us as the Fungi, we saw that the life-history of these organisms was full of the evidences of an evolutionary process in the life-world, and that the various progressive phases exhibited by them illustrated for us some of the steps by which the early single-celled organisms passed into and became the many-celled, complex, tissue-forming bodies of later times.

We saw, too, that this evidence was particularly clear and illuminating in regard to sex differentiation. For here within one group of organisms we might perceive and mark all the differential processes, actually taking place as it were under our very eyes by which the continuation of life, from its very dawn on our globe down to our own days, has been carried on and made possible; and further, that all these remarkable transitionary, developmental phases, as manifested in the life-history of this group of organisms, were wholly without explanation or meaning unless interpreted in terms of organic evolution.

The truth of this statement will come home to us with even greater force, as we seek in this chapter to learn and understand something of the significance and purpose of these sex differentiations we saw arising among the Fungi; and which play so vital and paramount a part in the realm of life as constituted to-day. We are so accustomed to sex differentiations that we do not stop to think about them. We take them for granted and imagine they have always existed; that life has always manifested itself under these dual aspects.

But it is clear from our consideration of the bacteria and the fungi that this is not so; and we shall see further, in our consideration of the import and purpose of sex differentiations in this chapter, that although sex distinctions have given to life so much of its interest and fullness and joy, especially for the higher organisms, they have not always existed, nor are they so essential to the continuance of life-forms as we have been accustomed to think.

They are clearly the product and outcome of the evolutionary process itself; and their primary purpose in the life-realm would seem to be to assist in this process.

Sex differentiation has enormously aided in bringing about that wonderful variety of form we see in the world of life to-day. The possibilities of variation have been tremendously increased by this dimorphic method of reproduction. The offspring draw from two lines of ancestry, with all their diverse characters and tendencies, instead of from one.

Many biologists look upon sex dimorphism or bi-sexual propagation as the chief cause of variation in life-forms; some holding that the male-cell by its differentiation has taken over all the active, dynamic qualities of the original, asexual organisms and thus initiates all the modifications by which new varieties arise; while the female-cell having now become relatively inert and passive holds back and checks this tendency to change inherent in living matter, and thus becomes the static

hereditary influence or factor in the reproductive process.

That there is some ground for this view seems to be clear from the experiments in artificial fertilization of ova carried on by Jacques Loeb and his school of biology. According to Loeb, the main instrument of heredity is the ovum. He found that he could activate the eggs of sea-urchins in several ways and induce them to develop into larvæ by artificial means without the use of the sperm of the male at all; but that on the other hand nothing would cause the spermatozoon to develop into a larva apart from the ovum.

He discovered further that the hereditary influence of the sperm upon the offspring in dimorphic unions was always in a ratio proportionate to the genetic relationship existing between the parents; that paternal characters could be transmitted to the offspring only when the sperm came from a male of the same or a nearly-related species; that if the sperm of a distantly-related species of sea-urchin was used no paternal characters were transmitted. The offspring showed only maternal characters, that is the characters of the species to which the mother belonged.

We may gather from these experiments, first, that the ovum is the essential and predominant partner in the reproductive process; and, second, that the ovum is able alone to carry on and transmit the characters of the race even in cases where the organisms concerned have reached the bi-sexual stage of reproduction.

We are prepared for this conclusion by what we saw taking place among the fungi. One of the methods of reproduction there, it may be recalled, was by the union or fusion of two female-cells in a species where the male-cell had not yet been evolved or was not functioning.

We may regard these differences of function in the reproductive cells as due primarily to "division of labor." It is clear that when the unicellular organisms had once entered upon the cluster or colonial state, differentiation in function would have necessarily to follow if these cell-clusters were ever to become the complex, closely-integrated bodies characteristic of the present-day higher organisms.

Sex differentiation will therefore, be best understood if regarded as the outcome of a "division of labor" among colonizing cells. It undoubtedly took place early in the history of organic life soon after the primitive single-celled organisms had become colonial groups, and may be regarded as one of the earliest steps in organic evolution.

The greater passivity and larger size of the female cell, is obviously due to the fact that in it is commonly stored the yolk, that is the food element necessary to the sustenance and growth of the new organism in its earlier stages. It is also the builder up, the constructive factor in the reproductive process; while the male cell is chiefly the energizer, the activator or starter of the process. Greater activity is obviously necessary on its part to perform the functions it has to carry on. One of these is to seek out the more passive and inert ovum before union with it can take place. It has also to supply in larger measure than the ovum does at this stage of evolution the energizing life-force so essential to the proper and full development of the new life-form; the absence of which causes the premature death of so many of the larvæ produced by artificial fertilization; and also the untimely shrivelling up and falling away of so much immature fruit from our bushes and trees. This last is particularly observable among cherry-trees, when for some reason or other the blooms have been poorly fertilized by the insects, or where the pollen brought by them has not been of the right kind. A single isolated cherry-tree, that is one rather remote from others of a like kind, seldom bears fruit that comes to maturity and ripens, though the tree may each season be covered with blossoms. The cherries wither,

shrivel up and fall off in the early stages of development, because they lack the vital-force conveyed by the male elements; the tree not being of the self-fertilizing kind.

We need not here at this point consider further the part played by the germ-cells in the transmission of parental and ancestral characters. This question will come up a little later when we have to deal with the mechanisms of inheritance. The point we want to bring out here is the meaning and purpose of the reproductive process and its relation to the kindred processes of regeneration and rejuvenation. For when these three processes are rightly viewed, reproduction is seen to be but a specialized form of regeneration and rejuvenation.

All three processes are essentially means employed by nature for the prolongation of life in the individual and in the species. In other words they are the mechanisms for the perpetuation of organic forms.

Regeneration manifests itself in various ways in the organic world and a very brief consideration of its processes soon convinces us that it is fundamental to sexual reproduction. It is more common among the lower life-forms than among the higher; but even here it is always at work though its activity is restricted to narrower limits.

Regeneration is always going on even in bodies as complex as our own. Worn-out and injured cells are always being renewed and restored. Every time a lesion is healed regeneration has taken place. Many marvellous instances of this regenerative power of the cells of our bodies were shown in the case of the soldiers injured in the late war. Graftings of bone and tissue met with success undreamed of in surgical science a few years ago. Restorations of lost parts, such as the nose, jaws, and face, were so perfectly effected that in many instances the scars were scarcely noticeable.

All these wonderful healings and all the marvellous successes that now commonly follow surgical operations in our hospitals are due as much to the regenerative power of our cells as to the skill of the surgeon. Indeed, without this regenerative power his skill would be of little avail.

Spontaneous regeneration of lost parts manifests itself in many ways and among practically all forms of life. Speaking generally this power seems to be conditioned by the complexity and organization of the organism. The greater the complexity and the higher the organization the less the power of regeneration. But there are occasionally remarkable exceptions to this general rule.

The best instances of regeneration are naturally found among the lower life-forms. Thus for example a starfish deprived of a ray or an arm, can spontaneously replace this by a new growth. In the same way, crabs and lobsters can renew the whole of their great-claws when lost in fighting or in any other way; and a lizard can regrow a lost tail.

The newt or triton has also great powers of regeneration and can regrow lost limbs or other portions of its anatomy. Nais and Lumbriculus, two kinds of segmented worms, can not only regrow lost parts but can regenerate the whole body from a small portion and even renew a lost head.

One of the most extreme instances of this regenerative power is furnished by those lowly forms of animal life known as the hydra. These primitive little water animals exhibit perfectly wonderful powers of this kind. Wilson has shown that some of the simpler forms can regrow the whole body from the tiniest bit strained through a cheese-cloth. They also lend themselves to grafting experiments, and some odd things have been done with them along this line. It was from our experiments upon these little organisms that we derived our earliest knowledge of grafting, a process that has since become so important in many surgical cases.

But similar powers of regenera-

tion are found in animals much higher in the scale of life than any we have yet mentioned. The ascidian, an aquatic creature which has the distinction of linking up the invertebrate animals with those with backbones, possesses likewise great regenerative powers. It is able to renew its whole body from practically any portion of itself with all its organs and specialized parts perfectly restored.

And, at times, this regenerative power crops out in organisms of advanced organization. Weismann has recorded an interesting case of this kind in a creature as highly organized as the stork. One of these birds had lost the fore-part of its bill in some way. In course of time the lost part was spontaneously renewed and the bill became as perfect as before the accident.

We may gather from this and other instances of a like kind, that although the higher life-forms have had to pay for their superior organization by a decided curtailment in their regenerative powers, the cells of our bodies still retain potentially, in considerable measure, their primitive powers of regeneration; and that these may be called into play at any time in exceptional circumstances.

It is possible that the genuine cases of so-called mental healing are brought about by this regenerative power which seems still to linger within the individual cells that compose our bodies.

Weismann was inclined to think that the power of renewing lost parts of an organism was in some measure due to their physiological importance. This was a deduction he drew from the case of the stork's bill. And it certainly seems that we have justification for this view in the light of the fact that the phenomena of regeneration are seen to be primarily and essentially methods of perpetuating life. If the organism could not regenerate an injured or lost part essential to its continued existence it would have to perish and pass away.

We may regard regeneration, then, as one of nature's methods of perpetuating her life-forms; and reproduction both asexual and dimorphic, as only another way of doing the same thing. For reproduction by budding and fission is at bottom only another form of regeneration, as becomes clear when we view it in its relation to rejuvenation.

Child's interesting and extensive experiments with planarians bring out the intimate and fundamental relation that exists between these two processes.

These creatures are a kind of flat worm, mostly aquatic in their habits. They are generally of an oval or elliptical shape and move about, as do many of the primitive animals, by means of vibratile cilia. They also have great powers of regeneration and lend themselves readily to many forms of experiment.

If we cut off isolated portions from the bodies of complete, mature individuals, these portions undergo regeneration and reconstruction and become complete forms.

But these experiments have some other suggestive features about them; certain conditions must be observed before restoration can take place. In the first place the several pieces must be of a certain size. If the pieces fall below this size only imperfect regeneration will follow. In the second place, the details of the regeneration will differ according to the level or part of the body from which the piece was taken; thereby showing that certain parts of the organism have more regenerative power than others. The process takes place as follows: In the course of two or three days, out-growths of new embryonic tissue appear on the surface of the cuts. During the next two or three days the forepart of the out-growth forms into a head with eyes, cephalic lobes and a new cephalic ganglion or nerve centre, and the hinder part into a new end.

From his experiments as a whole Child shows that the rate of metabolism of these regenerating parts is

practically the same as that in young planarians produced from eggs in the ordinary way. This is a very important point; for it seems to say that rejuvenescence is the outcome of regeneration.

He carried on this regenerative process through thirteen generations of new forms; each new form arising from a severed bit of one from the previous generation after it had reached maturity. The series then came to an accidental termination by the over-heating of the place where the experiments were being carried on.

As far as may be judged from these and similar experiments upon other organisms by other students, there seem to be good grounds for supposing that reproduction by these means could have gone on indefinitely. At any rate while these experiments are not absolutely conclusive on this point, they indicate as far as they go an unlimited power of rejuvenescence in the cells of these animals; for each generation of planarians brought into being in this way, renewed its youth by the regenerating process as if it had begun its life in the normal way from an egg.

We gather from this that the underlying factor in rejuvenescence is physiological activity. Induce physiological activity in a cell or body and rejuvenation of that cell or body follows as a natural consequence. Keep up the physiological activity of an organism and it can never grow old, would seem to be the logical conclusion to be drawn from these experiments.

This opens up an interesting question, but we must not pursue it further here, beyond saying that many biologists hold the opinion that what we call "death," is only an accidental occurrence in the life of an organism and not an inevitable one; or if so, in the case of the higher organism, it is the price they have been called upon by nature to pay for their greater complexity and higher organization. That among the lower organisms, where the propagation of new forms is carried on by budding or binary fission, there seems to be no reason why the parent-form should ever die except by an accident; as the very act of dividing and sharing its substance with its daughter cells increases its physiological activity, and thus rejuvenates it, making it actually young again.

Viewed in this way the reproductive process is seen to be the outcome and consequence of a high metabolism in cells and bodies; in other words of increased physiological activity, such as may be observed in both plants and animals with the on-coming of spring, after the relative inactivity and quiescence of the winter season.

Some interesting experiments carried on by Professor Woodruff of Yale on the animalcule, Paramæcium, aurelia, lead to the same conclusion besides incidentally illustrating the marvellous power of reproduction possessed by these lowly forms of life. He isolated one of these animalcula and watched it produce four new daughter-cells by binary fission. These four were then isolated to form the ancestors of four lines of descent. The pedigree culture was maintained over a period of five years by taking a specimen practically every day from each of the four lines.

In the five years there were 3029 generations; 452 in the first year; 690 in the second; 613 in the third; 612 in the fourth; and 662 in the fifth. The mean rate of division was in excess of three fissions in 48 hours. Now follows the point of interest. The original four animalcula were as healthy and vigorous at the end of the five years as at the beginning. They had also incidentally given evidence of the potentiality of producing, if every new form had been kept alive, a volume of protoplasm approximately equal to 10,000 times the volume of the earth! What a prodigious metabolism here! What a marvellous physiological activity! As observed before, it is among the

lower organisms that life is most exuberant.

These experiments seem to show us that given an ideally favorable environment there is no reason for death or even old-age among these simple life-forms, whatever there may be among the higher ones. They possess the secret of eternal youth, which the higher forms have had to barter away in return for their superior organization and other gifts.

The experiments of Child with the planarians go to show that rejuvenescence can take place in certain circumstances in the cells after maturity and old-age have overtaken them. They demonstrate for him the fact that the differentiated somatic or body cells can return to a physiological condition which approaches that of the undifferentiated germ or embryonic cells. This is an important deduction and has momentous bearings upon the transmission to offspring of acquired characters, as we shall later see.

At this point we are concerned chiefly with the evidence these experiments offer respecting the fundamental relation between the three processes of reproduction, regeneration and rejuvenation. We may perceive from them that nature can use any one of these processes as needs and circumstances require; for it is clear that they are fundamentally only so many different methods or means employed by her to preserve and perpetuate her life-forms.

We gather further from the facts of rejuvenation and regeneration that bisexual reproduction follows naturally upon the primitive methods of budding and binary fission when the unicellular organisms have by cell-aggregation passed into the multicellular condition of life. We gather also that the bisexual propagation of organic forms is primarily an outcome of that necessary division of labor among cells after cell-aggregation has taken place, and they have entered upon a corporate and interdependent existence; and that nature has taken advantage of the bisexual method of reproduction and made use of it for securing greater diversity of organic forms. By this means she has been enabled to achieve in the shortest time and by the most direct route, her final end and purpose in the life-realm—the evolution of man.

This brief consideration of some of the more salient facts of reproduction, regeneration and rejuvenation ought not to be brought to a close without some reference to the latest advances in the new Science of Experimental Biology. We have incidentally touched upon some of the wonders that are daily being wrought in this new field of research, such as grafting of lost parts and the reconstruction of fresh organisms from bits of older ones; and the artificial activation or fertilization of eggs. But these and similar practices are already the commonplaces of this new science.

Far greater wonders than any of these have been performed of late in our biological laboratories; and still greater ones are predicted and foreshadowed. We have learned how nature determines sex in her life-forms, and have taken the process out of her hand; and can now largely determine this question for ourselves. Nay, more, we can undo what nature has already done, and reverse the sex characters she has stamped upon an organism.

Sedate and matronly hens, which have laid honest eggs and brought up many broods of chicks, have been transformed by surgical operations into male birds, that not only assume the secondary sex characters, such as coloring and style of feathers, and crowing, but are able also to mate with other hens and fertilize their eggs.

But more even than that has been done. The ova of such animals as rabbits and guinea-pigs have been taken from the ovary and artificially fertilized, and the resultant embryos have been developed in a

culture serum and kept alive for definite periods in this way.

Some of the more daring of our biologists and eugenists predict startling developments along this line in the near future, not only among the lower mammals but also among the higher. They even go so far as to predict (as witness Haldane's "Dædalus, or Science of the Future") that a race of supermen may be brought into being in this unusual, extra-uterine way.

The future has doubtless many wonders in store for us, but whether this is one of them remains to be seen. The interesting point about it all for the evolutionist is the significant fact that man, the ultimate outcome and product of all nature's strivings, is taking the evolutionary and life processes out of her hand, and learning to mould and manipulate them for his own ends and purposes. Or, regarding the matter from another point of view, we may say that nature has been preparing for herself all down the long ages, a highly-specialized instrument, by which to carry out more intelligently and efficiently than in the past, her future purposes and plans in the life-realm; and that this instrument is Man.

CHAPTER XI.

Algæ

HAVING in the last chapter learned something of the meaning and purpose of bisexual differentiation; and the fundamental relation of reproduction to regeneration and rejuvenation; and having seen that they are only so many different phases of the evolutionary process; we can now with a clearer understanding of this process take up the consideration of that large group of lowly organisms known collectively as the Algæ, and learn what evidence they have to offer us in support of the doctrine of organic evolution.

In this group of life-forms we shall come upon stronger evidence of an evolutionary process in the organic world than any we have yet met with. For these organisms can show more clearly than either the bacteria or the fungi the actual steps by which unicellular forms have passed into, and become multicellular forms. Among them we may also perceive very clearly how division of labor first takes place; how sex dimorphism comes about; and finally how the early vegetable forms gave rise to forms intermediate between them and the animals; and how these again pass by insensible gradations into the animals. They bridge the gap between the animal and the vegetable worlds for us.

Under the term Alga (plural Algæ), which in its original Latin signification means "sea-weed," but which now has a much wider meaning, is included a vast array of differential life-forms divided into several sub-classes, many families, still more genera, and a multitude of species that run into the tens of thousands. As to races and varieties they are beyond computation. The law of variation has clearly been very active among them all down the ages, giving rise on the one hand to the specialized bacteria and fungi forms, and on the other to the mosses and higher vascular plants along one line of descent, and to the Flagellata or Intermediate—half-animal, half-plant—forms along another.

They are commonly divided into four sub-classes according to the coloring matter which characterizes them, namely, Blue-green Algæ; Green Algæ; Brown Algæ; and Red Algæ. Of these the first or Blue-green algæ are the simplest and most primitive forms. They undoubtedly represent to-day the earliest types of the algæ, and of them all have the widest distribution. They are found not only in the sea but also in brackish and fresh water lakes, and pools; and some specimens of them are found growing on moist earth, damp rocks and wood and upon trees. These latter are the greyish or greenish deposits one sees in these places. They are not only the lowliest of the algal forms but are at the same time the lowest and most primitive of all vegetable organisms known to us. In some respects they are even more primitive than the bacteria, to which they are most closely allied and with which they have many morphological features in common; for they have no outer membrane or containing wall as have the bacteria.

Concerning the cell contents of these lowly algæ there is much difference of opinion; some authorities holding that the chromatin has been segregated into a nucleus and others that it is scattered throughout the whole cytoplasm. The probability is that both conditions are found among them seeing that they

are admittedly related to the bacteria, whose cells normally show no nuclear differentiation. In the more advanced algæ, the nuclear condition is a common feature. We have already seen that the nucleated cell is later in time than the unnucleated cell and must, therefore, be a product of the evolutionary process. We would expect, therefore, to find the nucleus absent in the earliest algal forms as these share with the bacteria the distinction of being the most primitive life-forms we know.

Between the lowliest and the highest algal forms there is a wide degree of differentiation reaching from the microscopic specks of living matter represented by the lowly Chromaceæ—those greenish-grey unicellular growths we just now mentioned—to those compound forms of the larger life-world which have a stem-like and leaf-like structure as complicated as the mosses; and also a well-defined system of tissues and vessels.

It is impossible to trace this wide differentiation within a single group of organisms such as the Algæ, and give a satisfactory and reasonable explanation of it without postulating an evolutionary process; and it is not too much to say that the evidence from this group of organisms alone would make the doctrine of organic evolution a reasonable hypothesis, even if there were no other evidence at hand, so strong and clear is it. Let us here briefly give our attention to some of the more obvious phases of it.

In structure the Blue-green Algæ are both unicellular and multicellular. The simplest plants consist of a single cell which carries on all the functions of life as an isolated and independent organism. In another group we find these single cells have reached the cluster stage and are held together in a loose kind of communal life by an enclosing jelly-like substance derived from the cells themselves.

The simplest of the true multicellular forms consist of filaments which arise by repeated division of the individual cells in parallel planes. It thus becomes clear that these simple multicellular forms are directly derived from the single cells by a succession of fissions in which the daughter-cells do not separate from the parent, but by adhering together in this longitudinal manner form thread-like bodies.

Reproduction among this kind of algæ is, as might be expected, of a simple, primitive kind. It is generally by means of endospores formed by the contents of certain of the cells breaking up into spore-like bodies which are distributed in the form of fine dust.

Relatively simple in structure as these Blue-green algæ plants are, the group has within it eight distinct families, some 90 genera and about 1000 species. The varieties are too many to enumerate.

The Green Algæ are distinguished from the other three groups chiefly by the absence of any secondary coloring matter, and even among themselves they differ so widely in habits and character that they seem to have little else but their greenish color or chlorophyll in common.

They also include within their group both marine and fresh-water plants. In this group of algæ the "thallus" displays greater variation in form than in any of the others. It may consist, as in the Blue-green group, of a single cell which remains free for the greater part of its existence. During some part of its life however it enters upon the cluster or colonial state, in which condition it resembles the "resting" phase seen among the bacteria. These clusters form a kind of loose colony either by the adhesion of their cell-walls one to the other or in a common mucilage-like matrix.

This colonizing habit among the Green algæ has interesting features about it for the evolutionist. It shows progressive advance towards the multicellular structure. Indeed algologists tell us that it is extremely difficult to draw any distinction between a colony of unicellular organisms and a definite multicellular form, so insensibly does the former pass into the latter. In a Volvox sphere, for example, there is a marked protoplasmic

continuity between all the cells of the colony, just as is found in the simplest of the multicellular organisms, and when we reach the Ulvaceæ the transition has actually taken place. No one can follow this colonizing habit of the algæ from its earliest and simplest to the latest and most complex stages and have any doubt that we are watching the very steps by which the single-celled organisms passed into and became the many-celled organisms in the dawn of life-history.

In the Ulvaceæ group "division of labor" has taken place. We find localization of growth with distinction of parts; the colonial cluster of individual cells has given place to a differentiated, compound thallus or body formed of inter-related cells. If this is not evolution what then shall we call it?

In another division of this group of algæ we find still greater evolutionary advance. Among the Characeæ we may perceive the highest degree of differentiation. The thallus here grows upwards by means of an apical cell such as is found in the higher plant forms, which stem-like growth gives off whorled appendages at regular intervals from which arise branches; thus foreshadowing the external morphology or structural form of the highest plants.

In the matter or reproduction we find both asexual and sexual methods are followed in this group of algæ; and from a comparison of the different families within it, there remains no doubt at all in the minds of our highest authorities on these plants, that sexual, reproductive cells have arisen in the course of evolution as the result of a division of labor or specialization among the earlier asexual cells; one becoming female and the other male; the former being distinguished by its greater size and passivity and the latter by its smaller size and activity; features as we saw in the last article, which normally characterize sex-cells.

The Green algæ have during their life-history been subjected to even greater variation than the Blue-green kind. There are 27 families found among them; upwards of 230 genera; more than 3000 species, and races and varieties without number.

The Brown algæ, unlike the other two sub-classes we have been considering are almost exclusively marine plants. In this group are found the well-known forms of sea-weed common to our sea-shores.

Taking the group as a whole they show an evolutionary advance upon both of the other two; and they include among them, many very interesting forms. They, too, bridge the gap between the microscopic world and the world of larger life. Some specimens of them are very minute, filamentous plants requiring a microscope to detect them. Others are of considerable size and some are of enormous length, extending to many yards.

It is among these algæ that we see the earliest differentiation of the thallus into shoots and incipient roots, the latter appearing in the form of the so-called "hold-fasts," the means by which the sea-weed attaches itself to stones and rocks. In one of the sub-groups of these algæ called the Sargassaceæ we find a very high degree of external differentiation has taken place, rivalling in its variety the differences of form among the higher leafy plants. One striking feature of the more massive species of them is the development of air-vesicles in their tissues. These air-chambers serve to buoy up the plant when attached to the sea bottom. When such plants become detached from their mooring ground, as they frequently do in stormy weather, they float off and are carried to great distances by the winds and tides.

The Sargassa sea characterized by its prodigious growth of sea-weed, probably derives some of its material from this source.

Both asexual and sexual methods of reproduction are also found in this third group; the former being characteristic of the lower plants and the latter methods of the higher plants.

Among these we find not only differentiated sex-cells but also differentiated sex-organs such as we saw arising among the Fungi—oogonia and antheridia. In the way in which these appear we may again perceive the foreshadowings of the stamens and carpels of the higher flowering plants.

Sometimes these sex-organs are seen to occur together in the same cavity in the thallus, which is known as a conceptacle. At others we find each confined to its own special conceptacle. This may be in the same thallus or in a separate plant; thus again foreshadowing the later separation of sex-organs and sex-forms.

To this group of algæ belong those interesting shell-forming plants known as diatoms. The Diatomaceæ are wholly unicellular in structure and of microscopic size. They are chiefly distinguished from the other divisions of the algæ by their habit of clothing themselves in exquisite jackets of silica. Because of this and other animal-like habits they were at one time regarded as animals; but now they are definitely classed among the algæ as plants. They, too, have been deeply influenced by the law of variation; for they exhibit a bewildering variety of forms, most of which are most delicately and exquisitely sculptured. There are no more beautiful objects in the world than many of these tiny diatoms. They excel in beauty of design and form even those exquisite traceries and patterns assumed by frost crystals; and they are certainly among the most delicately beautiful things in our world. Some of these wonderful shelled-plants are exceedingly minute in size testing the highest powers of our microscopes to discover them. They play also an important part in the support of marine animal life; and in their habit of floating in the water display many striking instances of adaptation to their environment, all of which features are eloquent of the evolutionary process. The Brown Algæ have been subjected even more severely than the other sub-classes to the influence to the law of variation. This is easily seen by their classification which gives us 34 families, about 400 genera, and over 7,000 species. We do not attempt the enumeration of the variant forms. Their number is legion.

The Red Algæ are so named because of the red coloring matter they contain in addition to their chlorophyll. They, too, link up the two worlds of life—the micro-organic and the macro-organic—into a single whole, though the majority of their forms fall below normal vision.

They differ chiefly from the other three groups in the fact that there are among them no unicellular forms. They are altogether multicellular in structure though normally so tiny.

The thallus with them mainly takes the form of branched filaments, and their growth is by means of apical cells. They are interesting, too, from the evolutionary point of view, because they exhibit rudimentary leaves. In some species we find mid-ribs and veins which simulate closely the appearance of a leaf in the higher plants. In still another more advanced species we may see the lateral branches of the thallus actually assuming the form of leaves; and we are told by algologists that it is quite easy in these more compact plants to discern the differentiation in the cells comprising them. The whole process of metabolism may be observed taking place under our eyes. To the superficial cells belong the function of assimilation. The cells next below these are seen to be charged with reserve material; and the cells of the core of tissue are playing the part of carriers and conveying the materials of growth, which have been elaborated within the organism, from part to part.

Reproduction among the Red Algæ is carried on, as in the other groups, both asexually and sexually. It is noteworthy, however, that although all the members of this group are aquatic in habits, no zoospores, that is no motile or animal-like spores, are ever produced among them; a char-

acteristic they share with the Blue-green Algæ.

The classification of the Red Algæ shows us that the law of variation has been equally active in this division as among the other three sub-classes. There are among them not less than fifteen families divided into about 200 genera and at least 1400 speceis. The number of the varieties are proportionately great.

Taking the four sub-classes together we find their classification gives the following figures: 84 families; over 900 genera; and upwards of 12,000 species. The variant forms among these latter are beyond computation.

To the evolutionist it does not seem possible to explain this wide differentiation, both in form and function within one related group of organisms, in any other way than by regarding it as the result of an active evolutionary process.

We remarked earlier in this article that the Algæ alone were competent to uphold the doctrine of organic evolution, so full was this group of plants of the evidence of an evolutionary process. It will be easy to show by a brief recapitulation of our evidence that this statement has been sustained.

Within this group of organisms we not only find unicellular and multicellular, simple and compound, life-forms, but we actually see the steps and stages by which the latter are derived from the former; and so gradually does this transition take place that our best authorities are often at a loss to tell us when the organism has ceased to be a unicellular one, and has become multicellular in structure.

First there are the simple one-celled plants which lead individual and independent lives, each carrying on alone all the functions necessary to growth and reproduction. We observe these multiplying and reproducing themselves asexually by fission, or by budding, or by endospores. Among them there is no sex differentiation, no sex elements and no sex organs. These distinctions are wholly absent; they have not yet appeared.

Next we observe some of these unicellular bodies forming temporary clusters. At first these cell-clusters are loosely held together by a kind of mucilage derived from their cell walls. After an interval, more or less brief, the mass breaks up and the component cells resume their individual and separate existence as before.

Though it is not clear to us what purpose is served by these temporary clusterings, we are bound to assume that some mutual benefit results from the process or it would not take place. The activities of nature are never meaningless.

Later we observe that these cell-aggregations remain together for longer periods, and the union is seen to be of a closer kind. A difference in form, too, arises. Some take the shape of filaments which may be either single or branched, suggestive of the later stems and branches of the higher plants. Others are net-like or take the form of rings. Some are plate-like, and still others assume the form of solid or hollow spheres.

Whatever the form, the union is growing closer and closer. They have entered upon the colonial stage. At first the colonies break up for reproductive purposes and each cell becomes the source of a new colony. Many of these colonies are formed of a definite and constant number of individual cells. Thus in the genus Pandorina, the colony consists of 16 cells crowded together and surrounded by a thin gelatinous envelope. When the cells are mature and ready for reproduction these colonies break up and each of the 16 cells gives rise to 16 smaller cells each of which becomes invested with a gelatinous envelope and grows to the size of the original parent colony.

The bond of union in the simpler colonies is the jelly-like substance that holds them together. An advance upon this loose union is made when the cells come together and adhere to each other by their cell walls.

A still closer union is formed when the cells become united by protoplasmic threads, as in the Volvox group of organisms. Here the cells, which vary in number according to the species, running from 500 to as many as 15,000, are arranged in the form of a hollow sphere, and throughout the gelatinous substance, which holds the cells together, fine protoplasmic threads are seen to pass. The union here has become more intimate and interdependent. It has also entered upon the permanent stage. The last definite step towards multicellular structure has been taken. These groups do not break up.

In the next higher group, the Ulvaceæ, we perceive our colonies of single cells have ceased to exist. The true multicellular stage, has been reached; division of labor with distinction of parts has been definitely established.

It is impossible for the open-minded student of organic forms to take the four groups of organisms, represented by Gonium, Eudorina, Volvox and Ulva, and observe the gradually increasing complexity and closer integration of their cells and remain unconvinced that we are watching the very steps taken by the primitive organisms in their passage from the unicellular to the multicellular condition.

Gonium is a plate-like colony of cell units, each of which lives and feeds as a free and distinct individual in spite of its colonizing habit. The cells pass most of their life in this colonial state, separating only when mature for the purpose of reproduction, when each cell by repeated division gives rise to a new colony.

Now mark what takes place in the Eudorina group. Eudorina is a spherical colony made up of either 16 or 32 cells, each of which may give rise to new colonies by repeated division of itself as in the Gonium group. This method of reproduction may occur several times but does not go on indefinitely as with Gonium. Sooner or later conjugation of certain cells takes place. These conjugating cells have become differentiated from the rest. Certain of them are seen to increase in size. Others break up into 16 smaller elongated bodies. The larger ones are female cells, the smaller ones are male cells. Sexual differentiation has now taken place; division of labor has begun. The smaller cells colliding or coming into contact with the larger, conjugation by pairs takes place; and the zygote or impregnated body, resulting from this union of sex-cells, develops a cellulose cyst or case from which, after it has passed for awhile into a resting-state, there later emerges a new colony.

Here we see a decided and definite advance upon Gonium. The first step in differentiation has been taken and division of labor has come about. Now see what takes place in Volvox. Here the colony is a large one made up of hundreds or even thousands of cells. These cells are not only held together in a gelatinous matrix as in the two former groups, but each cell is now connected with the others by thread-like filaments of protoplasm. Integration is taking place; the first stage of multicellular structure has been reached.

In Volvox we perceive that cellular differentiation has proceeded farther than in Eudorina. There are now three distinct kind of cells. First there are the large female cells; second the smaller male cells, slender rod-like bodies, which have arisen from the subdivision of other specialized cells, in groups of 64 or 128; and third the remaining somatic or body cells, which make up the rest of the colony, and carry on its metabolic processes. These gradually and finally die and pass away. The male and female cells sooner or later conjugate, preferably with cells from another colony, after which the resultant zygote passes into the resting state, and later develops into a new colony.

In this group differentiation has gone further than in Eudorina. Here the colonies are approaching the condition of true multicellular organisms.

In Ulva we find this is definitely reached. In this group we find division of labor has wrought other changes. Here we have localization of growth with distinction of parts as well as the differentiation of the cells into male and female and somatic kinds. The aggregation of cells has ceased to be a mere loose colony; it is now a compact and differentiated thallus or body, made up of interrelated and closely integrated cells.

To the evolutionist these steps and stages; these graduated advances in complexity of structure; these increasing differentiations in cellular activity, have no meaning unless regarded as the outcome and working of the evolutionary process. And even when considered by themselves alone constitute no slight evidence in support of the doctrine we are examining. But when they are taken in conjunction with the many other lines of evidence, which all point in the same direction, they leave no room for doubt that in them we are watching the actual transformations by which unicellular organisms pass into and become multicellular bodies. In these processes, taking place under our very eyes today, nature reveals to us the progressive phases by which in the distant past she brought her higher and more complex life forms into being. And, as if to leave no room for doubt in our minds on this point, she recapitulates in the early embryological development of each of these higher forms, these very same steps and stages we have observed taking place in the algæ, as we shall later see.

CHAPTER XII.

Protozoa

IN our consideration in former chapters of the lower cryptogamic plants known collectively as the Thallophyta we found abundant evidence of an evolutionary process in nature. The wide differences found among these plants; their graduated advances in complexity of structure; and their increasing cellular differentiation resulting finally in a division of labor among the cells and in the appearance of distinct sex-characters, sex-organs and sex-forms, were seen to be wholly without rational explanation unless regarded as the outcome of an active evolutionary law.

A consideration of the higher cryptogams, which constitute the next two great subdivisions of the vegetable world—the Bryophyta and the Pteridophyta—more familarily known to us as the mosses, liverworts and ferns, would lead us to exactly the same conclusion, could we treat them with the same detail. But space will not permit of this. It must suffice to say here that the evidence to be drawn from these higher plant forms reinforces strongly that offered by the Thallophyta. And just as these latter ascend by numberless transitions and pass into the more complex, vascular mosses and ferns, so do the higher cryptogams grow more and more complex until they reach and pass into the highest sub-kingdom of the vegetable world—the Spermophyta—which includes all the higher flowering and true seed-bearing plants.

No one can study the plant world with open mind and a desire for the truth and follow the many transitional stages by which the simplest unicellular thallophyte ascends step by step to the more complex multicellular forms; until between them and the lowest of the mosses no essential differences in their structural characters can be found; and from these again through the ferns to the flowering and seed-bearing plants, and doubt the evolutionary doctrine or the genetic relationships which exist between these four great sub-divisions of the vegetable kingdom.

We may not always be able to point out the actual course they have followed or put our finger upon all the intermediate steps they have taken. The differentiations of these sub-kingdoms one from the other took place too long ago for every detail of their evolutionary history to be known; but no botanist today doubts for a moment their genetic relationships or that the higher plant forms are evolutionary developments of the lower. Every year new fossil forms are being brought to light which supply us with missing links in the evolutionary chain and lessen the gaps which now appear to separate one sub-kingdom from another. As our knowledge of Palæobotany, or fossil plant forms increases, the lines of the descent of the various phyla, classes and orders of plants, and their inter-relationships become clearer and clearer to us; and the day may not be far distant when botanists will be able to show us the very steps and stages by which the four sub-kingdoms became differentiated the one from the other. The very considerable advances made in this direction in late years give us warrant for holding such an opinion.

We may now leave the plant world, and enter upon our consideration of the animal world. In doing this, it is important to recall what was said in chapters VII and VIII with respect

to the fundamental unity of the life-realm, and the absence of any hard and fast line of demarcation between the Protophyta and the Protozoa—the earliest and simplest of the plants and animals known to us.

Nothing brings this out more clearly than the systematized lists, or classifications of life-forms, constructed by the botanist on the one hand, and by the zoologist on the other. We find that certain of these lowly organisms are claimed by both alike. In the eyes of the one, they are plants and are placed by him among the Protophyta. From the point of view of the other, they are animals and are accordingly classed by him with the Protozoa.

Among the higher forms of life it is of course easy to distinguish between plant and animal; the differences there are fairly obvious and deep-seated; but among the unicellular organisms this is far from being the case; the lines of differentiation are by no means always clear and obvious among them.

The characteristic distinction for instance, by which we commonly divide off the higher plants from the higher animals, namely, that of motility, or the power of spontaneous locomotion, fails us entirely when applied to many of the lower forms of life. Regarded from this point of view alone the bacteria would have to be placed in the animal kingdom, as at one time we saw they were; and likewise many other forms now classed by common consent among the plants. Motility we now know is as common among certain of the unicellular plants as among the Protozoa; and we also know that not all animal-forms are motile. Some are as sedentary or fixed in their habits and modes of life as are the typical plants.

It becomes abundantly clear, then, that it is impossible to draw any hard and fast line between the so-called vegetable and animal kingdoms. Nature recognizes no such divisions. They are purely the creations of our systematists; and though such divisions may prove convenient on the whole for purposes of study and classification, it should never be forgotten that the distinction is a purely arbitrary and artificial one. The life-realm is fundamentally a unit and the life-stream unbroken and continuous.

For the general purposes of division and classification, however, a fairly practical method of distinguishing between these lower life-forms has been found. This method is based mainly upon their mode of nutrition. To a modern naturalist, who is neither particularly a botanist nor a zoologist, the essential difference between a plant and an animal lies in the way in which it subsists or gathers its food.

For him an organism is a plant when it can subsist independently of other organisms, and is able to build up its substance directly from simple gases in the air and from inorganic salts drawn from the soil or water. A typical animal, on the other hand, is for him an organism which cannot do this and which cannot exist apart from other organisms because of its dependence upon them for its sustenance, having lost the power to draw its food directly from simple chemical substances, but must now seek it from the plants or other animals.

But even this criterion fails the naturalist at times. He finds organisms, which undoubtedly belong to the plant world, whose nearest relatives are all definitely plants, which, because of their saprophytic and parasitic mode of living, have entirely lost the power of extracting nourishment directly from inorganic materials; and on the other hand organisms, which as clearly belong to the animal world, possessing chlorophyll, and the plant-like ability of obtaining food directly from inorganic sources.

We made acquaintance with some of these ambiguous organisms, that dwell on the borderland between the two life-kingdoms and partake of the characters of both plants and animals, in our consideration of the Proto-

phyta. They not only show how closely the two kingdoms are linked together, but also give us some idea of how the one was evolved from the other. The Bacteria are some of these. Others among the plants are those active free-swimming bodies, the zoospores, we saw arising among the Fungi and the Algæ, and which were particularly observable among the colonial forms of the latter.

Inasmuch as these organisms display motile powers and possess swimming organs identical with those of the flagellate Protozoa they suggest to us the course of evolution of these latter.

Indeed, the close similarity between the flagellate plant and the flagellate animal forms renders it at times very difficult to say which is plant and which is animal or where the one ends and the other begins.

So much is this the case that formerly, before the modern method of distinguishing between plants and animals, spoken of just now, had been adopted, they were all placed in a class of their own known as the Flagellata, and commonly regarded as all belonging to the Protozoa or primitive animal forms.

Today, however, it is recognized that there are flagellate forms among the plants as well as among the animals; and thus in the Flagellata, whose common, dominant characteristic are their flagella or whip-like appendages by which they propel themselves, we see the natural link between the two life-kingdoms.

Taking both the plant and animal flagallete organisms together, they present a wide range of forms reaching from the simple, bacterial forms to the complex colonies of Volvox and Proterospongia—the ancestors of the sponges—and the highly-differentiated cells of the Euglenaceæ, of which the well-known genus Euglena may be regarded as typical. Many naturalists look upon these forms as the parent-group of the whole of the Protozoa; and whether this actually be the case or not, it is very certain we can draw no distinct lines of demarcation between the animal and plant forms. They merge insensibly into one another, and many of them are claimed as we have seen by both botanist and zoologist alike. With these preliminary remarks we may now proceed to take up our study of animal life.

In the animal world the Protozoa correspond to the Protophyta in the plant world. They are the simplest and earliest of the animal organisms; and just as the Protophyta by graduated, transitionary stages, and by increasing complexity of organization, passed into and became the Metaphyta—the higher tissue-forming plants—so did the Protozoa in exactly the same way pass into and become the Metazoa, or complex and compound, tissue-forming animals.

We may perceive the same evolutionary phases, the same graduated development, in the one as in the other. And just as it is impossible to draw any hard and fast line between the Protophyta on the one hand, and the Protozoa on the other, between the flagellate plants and the flagellate animals, so we cannot mark off by any sharp lines of difference the protozoan from the metazoan forms. And herein lies our basal justification for our belief in the doctrine of organic evolution.

Just as we saw the unicellular plants merging into and becoming multicellular forms, so we may perceive the unicellular protozoan merging into and becoming the multicellular metazoan, the main or essential difference between the two forms being the presence or absence of tissue. The Metazoa are characteristically tissue-forming animals; the Protozoa proper are not; they stop short of this stage.

Speaking broadly, the Protozoa are single-celled animals, each of which is capable of performing all the necessary functions of living organisms and maintaing a separate and independent existence when the conditions of life are suitable.

The Metazoa, on the other hand, are essentially many-celled animals in

which the constituent cells have become more or less differentiated for the performance of distinct functions. They have also combined together to form the various tissues that go to make up the compound body; and are normally no longer able to maintain a separate and independent existence apart from their fellows.

Between the two kinds of animals, and linking them together as among the plants, are the colonial or transitional forms. These display the same graduated, progressive complexity and cellular differentiation as was seen among the Protophyta. As with them, the simplest colonies are mere temporary aggregations of simple undifferentiated cells. These may be observed increasing in complexity of organization and in a closer and more intimate union of cells, until it becomes difficult to say whether they are more truly protozoan or metazoan.

In the study of the phylogeny, or ancestral history of the Protozoa we are not so fortunate as in our studies of the phylogeny of the plants. We can check up the conclusions reached in our studies of the living forms of the latter by the knowledge we can gather from their ancient fossil forms. We cannot do this in the case of the ancient forms of the Protozoa. We have to rely almost entirely upon the life-history of the various existing forms. The nature of so many of the Protozoa—their naked, skeletonless bodies—makes it impossible for us to discover fossil forms. All we can gather from the geological record today is that the differentiation of the main groups must have occurred at a very remote period in the earth's history, since the remains of those genera which possessed skeletons—such for example as the Foraminifera and the Radiolaria, whose structure and life-history indicate a very long pedigree—are found in the earliest fossil-bearing strata.

Notwithstanding, however, this lack of direct evidence in fossil-forms, we are not left entirely without guidance in our efforts to reconstruct the ancestral history of the Protozoa. There are several inferential lines of evidence to assist us.

One of these is the essential unity and homogeneity which is seen to underlie the numberless differentiations of form and structure we find among the Protozoa. We are justified in inferring from this that the phylum or group as a whole had a common ancestor. The working of the biogenetic law—that law which teaches us that the forms and characters of all young organisms are much closer to the ancestral type, from which the race or species has sprung, than are the mature and more specialized adult forms—also offers many valuable hints for our guidance.

The life-cycle of such groups of Protozoa as have been specially studied, such for example as the Mastigamœbæ—a remarkable group of amoebo-flagellate animalcula, which in themselves combine the peculiar organs of locomotion typical of two distinct classes, thus linking them together and showing their close genetic relationship—shows us that the adult forms among these organisms are preceded in the undeveloped young by much simpler ones; thus making it perfectly clear that the Mastigamœbæ are derived, and not primitive, ancestral, types.

Again, as we shall see when we consider, as we will in the next chapter, the different "classes" of Protozoa, that although the typical representatives of these classes present widely differing characters we yet find many of them of such an indefinite, intermediate type that we have often to use quite arbitrary measures in classifying them.

From facts such as these, of which there is no lack, we may perceive that the various evolutionary paths travelled by the Protozoa in their life-history all lead us back to a single, ancestral form. What this form was we will seek to discover in the next chapter.

CHAPTER XIII.

Protozoa (Continued)

IN the last chapter we saw how impossible it was to attempt to draw any hard and fast lines in the life-realm between plants and animals; that the Protophyta or primitive plants led insensibly into the Protozoa or primitive animals.

In this and the succeeding chapter we are to take up briefly the study of these latter and show that just as the Protophyta merged by progressive differentiation into the Metaphyta, so in like manner did the Protozoa merge into and become the Metazoa.

Simple and seemingly structureless as most of the Protozoa appear to be, there is, notwithstanding, a wide range of differentiation among them. Because of this, it is customary to divide them into four subdivisions or classes; and we cannot do better, in this brief consideration of them, than follow the same plan. Indeed, such a plan is peculiarly suited to our inquiry since it is based upon an ascending order of organization in these life-forms, the first class showing the least differentiation and the last the most.

Class I.—This is known by the descriptive term, "Sarcodina," also sometimes called "Rhizopoda." The creatures comprising this class are in their lowest forms little specks of naked protoplasm, devoid of any external membrane or limiting cuticle; that is to say they belong to the amœbiform organisms and are best represented by that common and well-known species Amœba proteus.

In these simple organisms we may see animal-life in the lowliest forms known to us to-day. Amœba proteus exists as a microscopic bit of slightly differentiated "sarcode" or bioplasm. It moves about and seizes the tiny particles of food it subsists upon by means of finger-like processes, called "pseudopodia," or "false-feet." These locomotive and grasping organs are merely temporary prolongations or protrusions of some part of the "sarcode" or body-substance. In form and general outline it is never constant, but is perpetually undergoing changes, according to its activity. When at rest it usually takes a spherical form. Hence the name by which it was first known, proteus animalcule, that is the "shape-changing" little animal.

It has no organs in the usual sense of this word, not even a primitive mouth. It takes in its food by engulfing it at any part of the surface of its soft, flesh-like body; the aperture by which it is taken in appearing at the point of contact, and closing up immediately after the engulfment, becoming again continuous with the surrounding parts; somewhat after the manner of a bog or quicksand.

It would be difficult to imagine anything in the form of an animal more simple in structure than a typical amœba. For this reason it has always had a special interest for the evolutionist; because he believes he sees in it, or perhaps it would be more correct to say, in an earlier and still more simple form of it, the remote ancestor of all the higher animals, past and present, including even himself; that between some such amœba-like organism and man there stretches a long line of connecting forms, some of which still exist, and others of which have long since perished and passed away.

Be this as it may, it is certainly an indisputable fact that we may see a general, progressive advance in or-

ganization, and an increasing complexity of structure as we pass from these simple amœboid forms to the higher and more specialized Protozoans. This will manifest itself as we proceed.

Class II.—This is distinguished from the other divisions by the term Mastigophora which literally means "whip-bearing" animals. In this group are included all the Flagellate protozoa; that is, those animalcula in which the organs of locomotion and food capture, or at any rate, as they appear in the mature or adult forms, are slender whip-like filaments. Like the pseudopodia in the Sarcodina class, these flagella serve primarily for locomotion and secondarily for capturing food. They are usually situated at the extremities of the body, and most commonly at the posterior end. Occasionally in some species they are found at both ends. When situated at the posterior end, they are known as "pulsella," because their movements propel the creature along. When found at the anterior end they are called "tractella," because their action in this case draws the body along.

Commonly each protozoan possesses only one of these appendages; but among certain forms two or even more flagella are found.

Among these Mastigophora the family of the Euglenidæ is one of the most interesting on account of the wide variation its genera have undergone; and because of the distinctive vegetative phases they pass through in the course of their life-cycle. Like the genus Volvox they are intermediate, ambiguous organisms, being at one time largely plant-like and at another largely animal-like. In some genera they are free-swimming forms, in others sedentary; in one they are naked, without any enveloping membrane at all, in another they are loricate, that is enclosed in a shell or other hard covering; here they lead single unicellular lives, and there they congregate together in extensive colonies more or less closely held together.

To the evolutionist they are chiefly interesting because of the vegetative or plant-like phases they go through in one period of their life-cycle, and because they are among those primitive life-forms that possess "eye-spots," the lowliest stage in the evolution of the organ of sight. In this class we also find that interesting interlinking group known as the Mastigamœba, to which reference was made in the last chapter, which combine, as their name implies, in the same individual the organs characteristic of both the Sarcodina and the Mastigophora.

Class III.—This group is distinguished from the others by the descriptive term Sporozoa. They are a parasitic kind of Protozoa found only as parasites in other organisms. They are, in the adult condition, wholly without definite organs of locomotion or ingestion of food; but when young they possess flagella.

This significant fact makes it quite clear that the members of this group of Protozoa have become highly-differentiated from an earlier ancestral form, and that they are obviously derived from a flagellate stock. They propagate themselves, as their name implies, by seedlike bodies or sphores containing one or more minute germs called "sporozoites."

In this method of reproduction they exhibit plant-life habits and afford us another excellent illustration of the far-reaching relationship between the two divisions of the life-realm.

Class IV.—This group is known by the term "Infusoria." They represent the highest and most advanced types of the Protozoa. They are also true animals having lost all the plant-like qualities of the less differentiated groups. They comprise all these Protozoa in which the organs of locomotion and food-capture are known as "cilia."

These cilia are small vibratile filaments of the same nature as the "flagella" of the Mastigophora, but

are distinguished from them by a difference in their mode of movement and by their smaller size. In the most primitive forms they cover the body of the animal in whole or in part like a fine fur. These cilia are present throughout life in the most characteristic group of the Infusoria known collectively as the Ciliata. In another sub-class they are present only in the immature stage of the organism, disappearing altogether in the adult period. These latter are termed Acinetaria or Suctorial Infusoria, and are particularly interesting to the evolutionist because of the modification they undergo, as they approach maturity, to fit them for the mode of life they have adopted. In their mature state they are non-locomotive or sedentary organisms. They begin their life as free-swimming animalcula; but in a short time their bodies undergo radical changes, becoming fixed and stalked. In this condition they develop radiating, retractile tentacles which have at their extremities disk-like suckers through which they imbibe their nutriment, these taking the place of the primitive mouth in the Ciliata.

The radical differences seen in the earlier and later phases of the life-cycle of these Suctorial forms, are very illuminating. They afford us another excellent illustration of the biogenetic law. Viewed in their adult stage they show little relation to the Ciliate Infusoria and we might never suspect their relationship to, or line of descent through this group, if we did not know their full life-history. It is our lack of knowledge of the life-cycle of so many of the lower organisms that makes it difficult for us at times to point out their genetic relationships. As our knowledge in this direction increases we shall be able to bridge many of the gaps that now seem to divide forms which may really be as closely related to each other as the divergent forms of the Ciliate and the Suctorial Infusoria are.

This brief consideration of the four classes of the Protozoa gives but the faintest idea of the immense variety of forms found among them today, or of the wide range of modification they have clearly undergone.

Relatively simple in structure as they mostly are when compared with the compound Metazoa, their long life-history and the changing conditions of their environment down the ages, with their adaptive response thereto, have wrought the widest possible differentiation among them. And yet throughout all the modifications they have passed through, and in spite of their almost infinite variety of form, it is impossible to entertain any doubt about the fundamental relationships which unite them into a genetically connected phylum or sub-kingdom.

Thus no one can fail to see how close is the relation between the Sarcodina and the Mastigophora on the one hand, and between these latter and the Sporozoa on the other; or between the two sharply-marked sub-classes of the Infusioria, the Ciliata and the Suctoria; or again between the Ciliated and the Flagellated Protozoa. Nor can they refuse to admit a progressive advance in organization from the simple amœboid Sarcodina to the relatively highly-differentiated Infusoria. Each of the four classes of the Protozoa is full of evidence of this kind. We have seen how the orders Ciliata and Suctoria in the Infusoria class are linked together by the common possession of "cilia" in the larval state of the latter; and similar links are found uniting the orders and families and genera in the other classes. In the Sarcodina, for example, the widest difference in organization exists between amœba proteus and the relatively complex Foraminifera, Radiolaria and Heliozoa or "sun animalcula," with their corticate bodies of definite spherical form and stiff, radiating pseudopodia. Yet, the intermediate forms between these divergent orders, being all marked by the possession of some kind of pseudopodia,

the characteristic feature of this class, plainly show their common relationship and the genetic descent by modification of the more advanced orders from the less advanced ones.

The link connecting the Mastigophora with the Sarcodina is just as plainly seen. Some of the former, such for example as Pseudospora, have to pass through an amœboid phase in their life-history before they reach the flagellate phase characteristic of their class.

Indeed, the distinction between the two classes lies largely in the use we give to the term "adult."

The typical, distinguishing feature of the Mastigophora are their organs of locomotion, their flagella; but these organs are as lacking in many species of their young forms as they are in the typical Sarcodina themselves; and at this stage of development they might very well be classed with the Sarcodina.

In the case of the genus Mastigamœba, the members of which exhibit both pseudopodia and a flagellum at the same time, they could be placed with equal propriety in either class. In the light of these facts there seems no escape from the conclusion that the flagellate Mastigophora are derived by modification from an amœboid ancestor; and the evolutionist could ask for no better evidence of the presence of an evolutionary process in nature than is found here. It is not an isolated instance either; numerous other examples of a like kind are found among the Protozoa. The link between the Mastigophora and the Sporozoa is just as plainly seen by the presence of flagella in the youthful phase of the latter class. Their descent by modification from a flagellate ancestor is as obvious from this phase of their life-history as is the descent of the Mastigophora from an amœboid ancestor.

In the same way it may be shown that the highly-specialized Infusoria are closely linked by structural characters and by transitional forms to the Mastigophora.

We are not, however, because of these facts, driven to postulate the direct descent of one class from another, though, if we exclude the Sporozoa, a very strong case of progressive descent could easily be made out; and, indeed, this is the view commonly taken by naturalists. There is, however, an alternative view we may take if this one does not satisfy us. Instead of regarding the more highly-organized classes as derived by modification directly from the less highly-organized ones, we may regard them all as having sprung separately from a common ancestor; and explain the differences found among them today as the result of divergent evolution.

This is in full harmony with what we have learned from our studies of other kindred groups of life-forms. It is the way, for example, in which we explain the remarkable affinities between ourselves and the anthropoid apes; between the tapir and the horse; the pig and the elephant, and other distantly-related forms. It is a point of view also which best explains the affinities we find among the various divisions of the Protophyta, the Bacteria, the Fungi and the Algæ.

Under either view we may regard the Sporozoa as standing—as do the Fungi in the plant-world—in a group by themselves, whether derived directly from the Mastogophora or from a common ancestor. Like the Fungi they have left the main current of life and drifted into side-eddies and back-waters of their own, and have played little or no part in the great drama of life. The life-realm furnishes us with many instances of this kind of evolutionary arrestment. The parasitic mode of life may make the struggle for existence easier for an organism, but such freedom from struggle is bought at great cost. It almost invariably leads to arrestment of progress and loss of growth;

and this to retrogression or degeneration.

It matters not greatly from the evolutionary standpoint which of these two views we may take concerning the phylogeny or ancestral history of the Protozoa; whether, under the many forms they exhibit to-day, they are derived through one more or less direct line of descent, or through several divergent lines; the many connecting links between them, and the essential unity and homogeneity which underlie their present diversity of form and structure, leave no room for doubt in our minds that they are all descended directly or indirectly from a single source or common ancestor.

What kind of an organism was this common ancestor it may be asked? Was it amœboid in character like the Sarcodina, or was it flagellated like the Mastigophora? And which is the earlier form, the amœboid or the flagellate? Can we tell which appeared first?

From what has been said about the simplicity of the lower amœboid Protozoa this question may seem easy to answer. But naturalists are by no means agreed upon the matter; nor is it as simple a question as might at first appear. There are certain features in the life-history of some of the lower organisms that somewhat complicate it. We saw in our consideration of the Bacteria that they are regarded by many naturalists as among the simplest of life-forms on the globe today, because amongst other things they are lacking in a definite nucleus, their chromatin being scattered more or less throughout their cell-substance.. This unnucleated condition of the chromatin is regarded by biologists generally as a sign of primitiveness. Yet in spite of this primitive characteristic a bacterium possesses an enveloping membrane and a ciliate organ of locomotion; both features which are supposed to characterize organisms much more advanced than Amœba proteus. Nor is this all. Amœba proteus is a naked animal wholly lacking a containing, enveloping membrane, and a flagellum or definite organ of locomotion; but yet at the same time possesses a distinct nucleus. And to make matters worse some specimens of the Sarcodina group possess in the youthful phases of their existence true flagellate organs of locomotion. How are these seemingly conflicting facts to be reconciled? How are we to decide which is the more primitive, the naked, unflagellated but nucleated amœboid form, or the unnucleated but protected, flagellated form?

When the question has been considered in all its bearings, however, very little doubt, we think, can remain as to which of these two forms is the most primitive, or as to the general characters of that ancestral form from which the Protozoa as a whole are conceived to have sprung.

No one can examine such an organism as Amœba proteus and doubt that its general organization is far simpler than that of the lowest flagellate form, its nucleated condition notwithstanding. Functionally considered flagella are clearly much more specialized organs, whether used for locomotion or food-capture, than are pseudopodia; and this fact alone seems to make the conclusion irresistible that amœboid forms of life preceded flagellate forms; and that the common ancestor of the Protozoa was an amœba-like creature that moved about and captured its food by means of some form of pseudopodia which early in the life-history of some of its descendents underwent modification and became permanent organs such as now characterize the flagellate plants, and the flagellate protozoa.

As was just now stated, when the life-history of the Protozoa is considered as a whole no room is left for doubt in our minds about the genetic relationships and the progressive advance in organization to be found among these forms. There is no necessity to further emphasize the fact. Our consideration of the sev-

eral classes into which the Protozoa may be divided must have made this abundantly clear.

In the next chapter we will direct our attention to some of the colonizing forms of Protozoa and mark how insensibly these associations of individual cells merge into and become the compound tissue-forming bodies characteristic of the Metazoa.

CHAPTER XIV.

The Metazoa

IN the last chapter we traced briefly the progressive differentiations found among the Protozoa and saw that we were irresistibly led to the conclusion, that despite the wide differences in form and structure, exhibited by the several classes into which naturalists have divided these lowly organisms, they were undoubtedly all genetically related, and must have sprung either directly or indirectly from a common ancestor; and that that ancestor must have been an exceedingly simple form, probably of the amœboid type.

We saw, too, that this progressive differentiation, this growing complexity in structure, could only be satisfactorily accounted for by regarding it as the outcome of an evolutionary process in nature. The limitations of space caused us to restrict our observations, and they were confined almost entirely to the organs of locomotion and food-capture. Had we taken any other phase of their organization the same conclusion would have been forced upon us.

The same progressive advance in structure and function, for example, would have been seen had we given our attention to the evolution of their ingestive apparatus, that is to their primitive mouths and gullets. Nothing illustrates better the presence of an evolutionary process in nature than the successive, graduated stages by which the definitely-formed and locally-placed cell-mouth, with its inward-leading tube, seen in the higher forms, is evolved from the indefinite and unlocalized, random openings, characteristic of such forms as Amœba proteus.

In the corticate Protozoa, that is in those provided with a distinct cuticle or outer covering, a special aperture for food ingestion becomes necessary. This, in the most primitive forms, is supplied by a tiny hole or pore in the cell wall. In the more advanced forms this orifice is prolonged inwards becoming a kind of permanent duct, which in the higher animals develops into a true gullet, or esophagus.

To observe, as one may among the Protozoa, the many transitionary steps and stages by which the random oral openings in the most primitive forms become the highly-specialized ingestive organs of the more advanced types, is almost to compel one to believe in an evolutionary process. Few things are more convincing. Nor is the evidence of progressive modification confined to the organs mentioned. It applies equally to all the specialized parts of the cell-body, such for example as the eye; and the processes we may perceive beginning in the Protozoan continue without break into the Metazoan forms.

We would lay special stress upon this fact, because in the early phases of the embryological development of the mammals we may perceive exactly the same progressive modification and evolution of definite organs taking place, step by step and phase by phase; the early life of the embryo thus recapitulating the evolutionary course of its remote ancestors before it begins to take on the special characters of its more recent ancestors and parents.

This progressive modification and advance is admirably illustrated in the intermediate or inter-linking forms that unite the two groups together.

Between the colonizing Protozoans, which exhibit the same associative

and integrative relations as we saw arising among the plant-forms—and, indeed, Volvox and its kindred genera are claimed by the zoologists as Protozoans—and the simplest of the Metazoan forms, such for example as Hydra, the step is exceedingly short, the difference between the two forms is seen to be merely one of degree of differentiation and integration. These processes have been carried a step farther in Hydra than in the colonizing Protozoa, the differentiation of the constituent cells has reached the tissue-forming stage, and the animal has now become a Metazoan. We may gather a pretty good idea of how this first came about from a study of the organization of the simplest forms of the Hydrozoa and the Sponges of to-day.

Let us take the latter first. The Sponges form a very large and varied group or phylum of their own, commonly known as the Porifera on account of their porous structure. At one time they were regarded as plants and classed with the Algæ. To-day the zoologist claims them and they are now classed as Metazoan animals. They are all water organisms and for the most part belong to the sea. They vary in size from minute, solitary individuals, barely visible to the naked eye up to large compound masses several feet in circumference. This large size is due to their powers of budding, each new cell remaining attached to the parent body. This aggregation of individual cells is one of the most interesting phases in the life-history of these lower organisms; for by a process of differentiation and integrative union, a union which becomes so close as to make it impossible to distinguish one cell from another, we are able to observe the actual passage of a lower into a higher form of life. From this new organism, thus formed by integration of individual cells, arises another and larger colony by rebudding, and we get as the final result the familiar bath-sponges of commerce, Euspongia and Hippospongia. Here we have the actual transformation of one order of life into another taking place under our very eyes; and this life-history of the common bath-sponge carries with it a very convincing suggestion of how the early uncellular forms became multicellular forms, and how the Protozoan passed into and became the Metazoan.

Concerning the lineage and exact position of the Sponges in the life-realm, naturalists hold somewhat different opinions. By some they are regarded as examples of Protozoan colonies in which integration of the individual cells has proceeded so far and become so close as to disguise their Protozoan characteristics, but which nevertheless still remain essentially Protozoan. By others they are regarded as true Metazoan forms derived by modification from Protozoan ancestors of the choanoflagellate or collared Monad type; and as forming a line of their own quite distinct from other Metazoan groups. By others again they are looked upon, by reason of their porous nature, as forming a sub-division of the Coelenterata—that is those simple animals with a distinct enteric or internal cavity, of which the Hydrozoa, to be presently considered, are typical examples.

These somewhat differing views of the zoologists need cause us no embarrassment. They do not weaken the evolutionary argument in the slightest degree. For under the first view it has to be admitted that the process of differentiation and integration, seen to be going on in the colonial Protozoa, differs in no discernable way from the same process that goes on in the Metazoan forms. The final result in both cases is the same, the formation of tissue; and this we saw constituted the essential difference between the Protozoa and the Metazoa. With the appearance of tissue-forming cells the individual cells of the Protozoan colony have lost their typical characters and in-

dependence; they have now become integrated members of a compound organism, in other words of a Metazoan. The only difference, therefore, between these two views is that the first regards them as highly modified groups of Protozoans, and the second as having definitely passed beyond this stage and become true Metazoans.

That they are thus derived from Choanoflagellate ancestors seems to be borne out by the significant fact that the characteristic cells, which enter so largely into the structure of all the Sponges, are of the collared and flagellate type. This points directly and most emphatically to a Choanoflagellate ancestry. This, moreover, is the prevailing view among zoologists and fits in best with the evidence at our disposal. And even those who hold the third view do not doubt the Protozoan origin of the Porifera. They merely regard them as possibly derived through a different line of ancestry. And it may be observed here that in regarding the Metazoan life-forms as genetically related to the earlier and simpler Protozoan forms no compulsion is laid upon us to derive them all through one line of ancestors. There may have been several lines of descent. The Metazoa may have had a polyphyletic origin. Indeed, the state of our knowledge at the present time points strongly to at least a diphyletic or two-fold origin for them; one, by way of the Sponges which form a line of their own, and the other and more fruitful line, through the Enterozoa or hollow-celled organisms, which lead on to the Coelenterata and these again to the Coelomata—those animals having body-cavities of a still higher order than the Coelenterata—and so onwards to the highest divisions of the animal world.

But whatever view one may hold concerning the descent of the higher Metazoan forms, whether through the seemingly barren Sponges, or through the Enterozoa, or some other unknown form, nobody can study the Porifera phylum and doubt that it leads back directly to the Protozoa.

The very fact that all the sponges are of colonial formation,, products of the budding process, differing only from the colonial forms of the Protozoa by the greater differentiation and integration of their individual cells, leaves little room for doubt as to their origin or the evolutionary course they have followed. And when we examine such simple, minute forms as Olynthus and mark the simplicity of structure we find among them, we feel certain we are looking at one, at least, of the links which unite the Metazoa to the Protozoa.

Olynthus is the simplest member of the Sponge group known to us today. It differs but little in structural formation from the colonial groups of the Volvox family; the individual cells composing it being slightly more closely integrated than in those. It is a minute thin-walled sac attached at the lower end to some rock or sea-weed and enclosing a relatively spacious internal cavity. This is the gastral or digestive cavity, and it opens to the outside by a vent or little mouth at the upper extremity of the sponge. Its thin wall is also pierced by numerous small pores. Lining the gastral cavity, the mouth and the pores, are a number of distinct collared and flagellated cells similar to the Choanoflagellated cells found among the Protozoa. Indeed they appear to be absolutely identical with these. They are set close together, and by the motion of their whip-like flagella a continuous stream of water is kept flowing through the sponge-body. Besides these fixed cells there are certain others which are free, like the white corpuscles in the higher animals, and have the power of wandering about from place to place in the sponge-wall. Some of these apparently convey food material to the different parts of the sponge; others of them appear to give rise to germ-cells both ova and spermatozoa. Now, all these cell differentiations and func-

tions are practically identical with those we saw taking place in the Protozoan colonies of Volvox, Eudorina and Ulva; and these simple Metazoan forms differ in no way we can discern from them save in a slightly closer integration of the individual cells; and this difference seems less here than that between the colonies of Gonium and Ulva.

Whatever doubt, therefore, there may be concerning the genealogy of those lowly Metazoans, the Cœlenterata, there appears to be little room for doubt about that of the Sponges. They most certainly seem to be directly derived from some of the colonial groups of the Protozoa, thus plainly showing that the colonizing habit as we have repeatedly pointed out was the way by which the unicellular organisms passed into the multicellular condition.

And now having established the genetic relations between the Protozoa and the Metazoa by means of the Sponges let us pass on from them to the Hydrozoa and see what relations we may discover there. Outside of the Sponges they are the lowliest of the present-day Metazoans and in their simplest forms show but little advance upon the Protozoans.

They occupy a position in the animal world very similar to that of the Algæ in the plant world. They form one of the most widely-spread and prolific groups of aquatic animals. They are mostly marine in habitat, but one of the best known of them is the little fresh-water creature common to our ponds and ditches, Hydra viridis, so called on account of its vivid green color, due to the presence within it of a large number of chloroplastic corpuscles, which are looked upon by some naturalists as parasitic or minute symbiotic Algæ. This little fresh-water animal is the simplest of the Hydrozoan forms. It is wholly lacking in any well-defined organs. Its body is a simple hollow sac with a disk-like foot at one end. Its star-shaped mouth is situated on the top of a conical elevation at the other end. It feeds by means of tentacles which arise at the point where the mouth-cone joins the body of the sac. These tentacles convey the food to the mouth, the undigested parts being later ejected through the same opening.

It is a two-layered animal possessing a typical ectoderm or outer layer which protects the animal and also serves as a generalized sense-organ; and an inner layer or endoderm.

In these simple Metazoan forms we find that a definite differentiation of the organism has taken place. There is now a distinctive outer part and an equally distinctive inner part. This two-fold differentiation and division of the cells into distinct layers is a feature which characterizes all the Metazoa; only in the higher forms a further differentiation into a third layer takes place which is known as the middle layer or mesoderm; and not the least interesting feature about these simple Hydroids is the fact that we may see a dim foreshadowing of this third layer in the jelly-like, non-cellular substance, which separates the outer from the inner layer. When seen in microscopic section, it appears as a thin line between the ectoderm and the endoderm. Though possessing no specialized organs beyond the mouth, tentacles and crude foot, Hydra viridis, shows signs of the beginning of a nervous system within it. Some of the cells of the ectoderm have become slightly specialized; for the animal shows a kind of response to different degrees of light and to touch. It also manifests a low order of motor activity moving in a crutch-like way with its tentacles and foot.

And just as we are able to detect a differentiation of function in some of the cells of the ectoderm so we may see the same taking place in the endoderm. The cells here show differentiation into what, in the

more advance forms, we should call glandular and digestive cells. From the former flows a kind of secretion that acts upon the food taken into the gastral-cavity much as the dissolving ferments break down the protein in the higher animals. But the primitiveness of these glandular cells is seen in the absence of those enzymes which are needed in the higher animals to dissolve the carbohydrate elements, since starch granules when taken in are ejected with the other excreta unchanged in character.

Regarding the Hydrozoa as a whole we find the same evidence of progressive differentiation among them as among the Sponges. Between the simple polyp forms and the most complicated of the Hydromedusæ there is a world of difference. If we exclude the sub-division Anthozoa—which includes the sea-anemones and corals—all but the simplest forms, such as Hydra, undergo a curious transformation at one period of the life-cycle, almost as radical as that of the caterpillar and the butterfly. They manifest what is caled "alternation of generation"; at one time being a simple polyp or colony of polyps and at another something quite different, a medusa, of which the umbrella-like jelly-fish, in its various forms, is a typical example.

These transformations reveal a phase and a condition of things in the phylogeny of these organisms concerning which we have as yet but little certain knowledge; and there exists some difference of opinion among naturalists regarding these transformations. The prevailing opinion however, is that the evolution of the free-swimming medusa-form came about to enable the sessile or fixed polyp to spread itself more widely and thus enlarge its habitat. Under this view of course the polyp is considered as the ancestral form, the medusa as the derived and specialized form, so specialized primarily for reproductive purposes.

That this probably represents the true state of things seems borne out by the fact that the simplest polyp forms, such as Hydra viridis and its kindred species, never develop into medusæ. The same is true of all the Anthozoa—the sea-anemones and coral polyps. The method of reproduction, too, among the Hydromedusæ is commonly a more advanced one than among the Hydroidea.

Among the former we find distinct sex-forms. The medusæ are either males or females. This distinction we have seen to be a sign of advanced organization, a product of the evolutionary process. This would indicate, therefore, that the medusa-phase is an advanced and derived one; for among Hydra, on the contrary, the individual as a rule is bi-sexual, or hermaphrodite, that is each possesses within itself both sperms and eggs; a feature characteristic, as we have seen, of the lower organisms only.

Moreover, the fact that although the Medusa usually reproduces itself by sexual methods it can and does under certain circumstances reproduce itself asexually as well, by fission or sporogony, thus plainly showing that notwithstanding its advanced organization, it has not yet entirely lost the habits of its simpler ancestors and may revert to them. And that the organization of the Medusa is an advance upon that of the polyp is clearly shown again by the thickening of the mesogloea, the jelly-like substance between the ectoderm and the endoderm. In the Medusæ this dividing matter approaches more closely to the true Mesoderm layer of the higher life-forms. It may contain cells which have migrated into it from the ectoderm or endoderm or it may be traversed by processes connecting these two layers.

Perhaps the strongest evidence of all of this progressive differentiation is seen in the ingestive and sense organs. These exhibit an enormous advance upon those of the simpler polyp forms. Thus the oral opening

or mouth leads directly into a true digestive cavity which is divided into a distinct esophagus and stomach, from which a series of canals radiate outwards; the whole, mouth, stomach and canals forming a gastro-vascular system much in advance of that of Hydra viridis, and clearly foreshadowing the still greater advances of the next higher class of animals.

A corresponding advance is seen in the sense-organs. These in the Medusæ are of two kinds: (1) pigment spots called ocelli or little eyes, which are sensitive to light rays and which in the highest forms are seen to develop into eye-like structures, with a primitive lens and retina and a vitreous body as in true eyes; and (2) organs of balance or orientation called statocysts.

Another feature of like significance in the life-history of the Hydromedusæ is the fact that in reproduction by budding, the medusæ always arise from the polyp or from other medusæ, but never the polyp from the medusa. When the polyp arises by alternation of generation from the medusa, it is always by means of eggs. We can entertain no doubt, therefore, that the transformation of the simple polyp into the relatively complex medusa is the result of the presence and working of an evolutionary law. It is a progressive advance, whether it be regarded as merely a means or device of nature to bring about a wider dissemination of polyps; or whether we regard the medusa as a new and separate organism able to reproduce itself directly by budding. The fact that it is able to do this marks its separateness and relative independence; just as its giving rise to polyp forms by sexual methods of reproduction, shows its line of descent from, and relationship to, these simpler and earlier organisms.

CHAPTER XV.

The Earliest Vertebrates

IN the last chapter we traced the progressive evolution of the colonizing one-celled Protozoa into the lower divisions of the many-celled Metazoa. Up to this point the evolutionary course has been clear and direct. The existence at the present day of the lowly organisms we have had under consideration enables us to more than surmise as to the methods nature has employed to bring about her ends. We get actual glimpses of the way in which her transformations have been effected. The links are obvious and close. But from this point onwards the course of the main line of advance is not always as clear as we might desire. Links are missing here and there; and, although there are hints and suggestions without number, and the cumulative force of the evidence taken as a whole, of progressive evolution, allows no doubt to remain in our minds that this principle has been actively at work in the life-realm all down the ages, the actual steps and stages followed are sometimes a little obscure.

We should not be surprised at this when we consider the enormous periods of time that have elapsed since the dawn of life on our globe, and the multitudinous changes and modifications that have obviously taken place here in the past. The marvel really is that we should be able to trace back with any degree of certainty at all the main course of life, amid so much diversity of form and structure as we find in the organic world today.

But the labors of our zoologists during the past half-century or so have succeeded in bringing a remarkable amount of order and sequence into this bewildering diversity; and the genetic relationships they have already established between the different groups of life-forms give us warrant for thinking, that as our knowledge of the fossil forms and of the life-cycles of the lower living forms increases, few of nature's secrets or her transformations in the past will be wholly hidden from us.

From this time onward in our survey of the Metazoan forms we shall be able to make more rapid progress. It will not be necessary to give them the same amount of detailed treatment as we bestowed upon the earlier forms. Our specific consideration of these has made it perfectly clear that the changes and modifications we have seen going on among them can only be adequately and rationally explained by postulating the presence and activity of an evolutionary process in nature.

We shall assume, therefore, that this process has been amply and convincingly demonstrated; and such further evidence as we shall gather on this head, as we proceed in our inquiry, will be only so much more additional proof of the existence and operation of a principle already well attested and established.

Zoologists have divided the Metazoa into a number of distinct phyla or sub-kingdoms. These fall naturally into two divisions distinguished from each other by the terms Parazoa and Enterozoa. The first is a small unproductive division comprising the single phylum of the Porifera or Sponges, which we have already had under consideration and which appears to constitute an independent order of life of its own. The other and larger division is made up of all the remaining phyla.

Because of the deep-seated dif-

ferences in the structural characters of this division it has been found convenient to separate them into two groups, a higher and a lower, termed respectively Cœlomocœla or Cœlomata and Enterocœla or Cœlenterata or (more briefly) Cœlentera. (Unfortunately for the biological student no general usage in zoological terminology has yet been established. Hence he will find his authorities, as in this instance, employing different terms to express or designate the same idea or thing.)

The Hydozoa, which we considered in the last article, are typical examples of the lower group, the Cœlentera. These, it will be recalled, are characterized by their two-layered organization which comprises an ectoderm and an endoderm and a single gastro-vascular cavity or cœlenteron.

The higher group, the Cœlomata, are differentiated from the lower by the possession of a third cellular layer, known as the middle layer or mesoderm, and by a cœloma or secondary body-cavity distinct and apart from the cœlenteron or intestinal cavity of the lower Metazoan forms; which, as we saw, served the various purposes of digestion, excretion, circulation and often reproduction.

There is thus between the higher and lower groups, the Cœlomata and the Cœlentera, a considerable structural gap; and it is interesting to us, from the evolutionary point of view, to note that one of the lowliest phyla of the higher group—the Echinodermata—is able to offer us some strong suggestive evidence of how the progressive differentiation which separates the two groups came about. For while the Echinodermata belong structurally to the Cœlomata, they have at the same time so many features in common with the Cœlenterates that some of our systematists have classed them with the latter. They are now, however, generally regarded by zoologists as belonging to the less differentiated of the Cœlomata group.

Under the term Echinodermata are included such marine forms as the crinoids, sea-urchins, star-fishes, sea-cucumbers, etc. In their characteristic forms they represent one of the most distinct types in the animal kingdom; and yet they also show at the same time, in diverse ways, their affinities to, and their direct descent from the earlier and simpler Cœlentera. Thus, they began life as free-swimming, ciliated embryos; the adult form arising from the larval condition by a secondary development, such as we saw characterized the Hydromedusæ; and the study of their life-cycle makes it reasonably certain that the phylum has been derived by modification from Cœlenterate ancestors. Indeed their relatively advanced organization is actually foreshadowed for us in some of the Cœlentera. Among some of these the enteron, or single body-cavity, takes on an elliptical form, and we may see taking place at the end of this, the development of a ciliated channel, along which the creature's food is swept. We have only to suppose the approximation of the two sides of this narrow elliptical aperture and their ultimate fusion—and we have seen far greater modifications than this—to perceive how the typical radially-symmetrical cœlenterate was transformed into the typical bilaterally-symmetrical cœlomate, with mouth and gullet at one end of the long axis and the anal opening at the other.

That they are thus derived from more primitive forms is clearly shown by their embryological and larval conditions. As free-swimming ciliated larvæ they point strongly to a ciliate ancestry. Historically considered, they appear in successively higher forms; the two fossil orders known to us being of much more primitive type and structure than the present living forms. Taking into account the rays of the star-fish and of sea-urchins, they would seem to suggest descent from some of the primitive flower-like, stalked forms which we considered in previous

chapters. The Echinodermata may thus be regarded as linking up and bridging over the gap between the Cœlentera and the Cœlomata. But because of the distinctive characters that mark them off from the other animals it is clear we cannot regard them as standing in the direct line of descent of the higher forms.

Like some of the other distinctive phyla, they form a group apart, their evolution having followed lines peculiar to themselves. One of the most interesting of these other phyla just referred to, the structural characters of whose members show quite plainly their departure from the main evolutionary line at an early period, is that which some systematists have called the Appendiculata and others Arthropoda, meaning thereby animals of the invertebrate class possessing jointed or articulated limbs.

This phylum is a very extensive one, comprising as it does about four-fifths of the whole animal kingdom. It includes within it the three great groups or sub-phyla of the Insecta—the number of whose species is believed to exceed that of all other animals taken together—the Crustacea (crabs, lobsters, shrimps, etc.) and the Arachnida (spiders, scorpions ,etc.)

The ancestral form from which this comprehensive phylum is descended was certainly some annulate or worm-like animal. This we may gather from the study of the embryos and larvæ of the various members of this group; and also from our observation of some of the simpler, more primitive forms among them, such as the Chætopods, worm-like annilids which have not yet reached the distinctly segmented stage of the characteristic forms of this phylum.

It would seem at first sight a far cry from some simple worm-like creature to such dissimilar animals as bees, ants, crabs, lobsters and spiders; and if the links connecting them up were wholly absent or lost to us it would be a hopeless task to endeavor to trace out the genetic relationships of such divergent forms. But, happily for the evolutionist, these connecting links are not wanting. Enough of them are known to us today to remove all doubt about the ancestral history of these widely-differentiated animals.

The discovery and tracing out of the relationships of the various classes and orders of the Appendiculata to each other, and these again to some common, worm-like ancestor, is one of the major triumphs of modern zoological science.

Another of the distinctive Metazoan phyla, which lie outside the direct line of ancestry of the higher forms, is that comprising the Molluscs. These include all the shellfish (other than the Crustacean forms belonging to the Appendiculata) together with the slugs, snails, etc.

The origin of this group is similar to that of the Appendiculata. They also have been shown to spring from some worm-like ancestor.

In tracing back, therefore, the line of descent of the higher vertebrates we have to set aside and exclude from our survey such distinctive phyla or sub-kingdoms as the Echinodermata, the Appendiculata and the Mollusca. They do not lie in the direct line of descent of the higher life-forms. They are side products of the evolutionary process; collateral branches in the great tree of life. We have to go beyond them to some earlier, less differentiated form. But when we do this we discover that the main line itself has also had its source in a worm-like progenitor; and in this fundamental fact we are able to perceive the underlying bond which links and unites the several phyla or life-divisions into one genetically-related whole.

From the higher worm-like forms to the simplest fish-like forms is no great step; and although the transformation took place too early in the pre-Cambrian seas for us to be able to trace the various successive phases by which it came about, we can have no doubt that this was the mode of

origin of the earliest marine vertebrates. We find the two great divisions of the animal kingdom, the invertebrate and the vertebrate, so closely linked together by intermediate, overlapping forms, which partake of the characters of both groups, that it is impossible to doubt their fundamental, genetic unity. We find suggestions and even traces of the earliest kind of a backbone in some of the higher kinds of worms themselves. Thus in the acorn-worms a kind of notochord is seen to occur and hence they have been termed Hemichorda. We can entertain no doubt, therefore, that some early worm-like animal gave rise to the lowest division of the vertebrates, the Tunicata. These intermediate forms possess a "urochord,' that is a caudal or tail chord, which represents, we believe, the primordial stage in the evolution of the spinal column of the vertebrates.

The best known of these Tunicates is the ascidian, more familiarly known as the sea-squirt; a soft-bodied animal of sac-like form. Its chief interest for the evolutionist lies in the fact that it begins its life as a free-swimming, tadpole-like creature; and while in this larval stage of its existence shows direct affinities to the vertebrates by the presence of a "urochord" or incipient spinal column; and although by a process of degeneration, having abandoned an active life for a sessile one, it loses this vertebrate character as it matures, the biogenetic law—which teaches us that the larval forms of animals indicate their lines of descent more clearly than do the adult forms—makes it quite certain that the sea-squirt is one of the connecting links between the soft-bodied invertebrates and the animals with a backbone.

There can be no doubt about this because other members of the Tunicata, which lack the degenerate tendencies of the sea-squirt, retain throughout their lives this characteristic, urocordal structure.

In the Tunicata, then, we see the earliest types of the chordate animals, the intermediate or transitional forms which unite the invertebrates to the vertebrates.

Between the tunicates and the lancelet, the lowest of the true vertebrates, the gap is slight. This fish-like marine form is a skull-less, thin, almost transparent, spindle-like creature, two to three inches long. Its chief characteristic is its soft, rod-like notochord or primitive backbone. It differs chiefly in this respect from the tunicates in the fact that this spinal-chord runs through the whole length of the body and is not, as in them, confined to the caudal portion only.

From the lancelet to the earliest true fishes the step is even shorter than that between it and the tunicates. Of how this step was taken we may gather some indications from the structural characters of one of the earliest of the fossil fish known to us today. This fish, to which the name Palæospondylus has been given, belonged to the Palæozoic age and was found in certain Scotch sandstones laid down in those far-off times. It is a small animal, possessing the simplest and most primitive type of a cartilaginous backbone known to us today. It is wholly without ribs or other extensions of any kind, and in character appears to stand just about midway between the backbones of the later fishes and that of the lancelet.

Should, however, the evidence of the descent of the vertebrates from some earlier, worm-like ancestor, afforded by this and other fossil fish, by the lancelets and the tunicates, still leave some uncertainty in our minds on this score, we have only to consider the supplementary evidence offered by the embryological development of the living vertebrates themselves to feel reasonably sure that this was the manner of their evolution. For in the early embryological life of the young of the present-day vertebrates we may observe the recapitulation of many

of these evolutionary phases taking place under our eyes. We may see the embryo passing from the chordless state to the notochord condition; from this to the cartilaginous, fish-like stage, and from this again to the characteristic, bony, spinal column of the higher fish and mammals.

When we consider all these converging lines of evidence and see how they confirm and strengthen one another, very little room for doubt can be left in our minds concerning the origin and mode of descent of the vertebrates.

In the next chapter we will continue our consideration of the aquatic vertebrates and seek to learn how these gave rise to the Amphibia.

CHAPTER XVI.

The Amphibians

IN THE LAST chapter we traced the evolution of the primitive chordates from some early invertebrate sea-worm. In this article we are to consider the first appearance of those animals which link up the land vertebrates with the aquatic vertebrates —the Amphibia. These, as their name implies, are creatures which live a double life, partly on the land and partly in the water.

But we must exclude from this category all those warm-blooded lung-breathing animals such as seals, walruses, sea otters, etc. These present-day terrestrio - aquatic mammals, though popularly classed as Amphibia, are not so regarded and classified by zoologists. They are not what we have to consider here. They are examples of the principle of "reversed evolution," of which there are many instances in the life-realm, of animals whose mammalian ancestors left a land existence for one in the water, impelled thereto, it may well be, by the fierce struggle for terrestrial existence; just as in the palæozoic age some of the aquatic animals were forced to adopt a life on the land by reason of the intense pressure of the teeming, exuberant life in the littoral regions of the seas. They are not classed with the Amphibia proper. We mean by that term here only vertebrates which breathe in the early stages of their lives by means of fish-like gills, and which generally later lose this method of respiration and acquire and breathe through lungs. The best-known members of this group are the frogs, toads, newts and salamanders.

All these normally begin life in the water as fish-like animals possessing and breathing through gills after the manner of true fish, thereby plainly showing their aquatic origin and their genetic affinity to the earlier water chordates.

Between these well-known examples of the Amphibia and the gill-breathing fish, we have a less-known, intermediate type of Amphibia, from the study of whose more rudimentary characters we can gather some very clear indications of how the lung-breathing vertebrates arose by progressive differentiation from the more primitive gill-breathing chordates.

These intermediate forms are called Dipnoi, or lung-fishes, the term signifying "double breathers," or animals that breathe in two ways. They have both branchial (gill) and pulmonary (lung) respiration. Hence their name. Great numbers of fossil fish of this kind are known to us; also a few living forms found in different parts of the world.

The lungs of these creatures are transformations, it has been found, of their sounds or swimming bladders. These are sac-like organs common to many kinds of fish. They are filled with air, their principal function being to regulate the equilibrium of the fish's body in its native element. Ordinarily this sound is a single sac, but in all the modern lung-fishes, with the exception of the Australian form, it is seen to double itself in the young fishes and develop into two primitive lungs. One is not surprised to find a single lung only in the Australian lung-fish. The fauna of this region is noted for the primitiveness of its types and we may conclude from this fact that the one-lunged fish of Australia represents an earlier and simpler form of the Dipnoi than do the two-lunged fishes of other regions.

The passage from the gill-breath-

ing to the lung-breathing fishes was not the work of a moment. It was undoubtedly marked by many transitional phases and intermediate forms. It is possible to gather some idea of how the transformation came about by observing the habits and characteristics of such modern fish as the migrating eel and others of that kind. This water-breathing animal is apparently able to carry on respiration out of the water for a considerable time as it travels overland from one stream or body of water to another. There is also a strange species of fish known to us which at times leaves its natural habitat and by means of its peculiar spiky fins climbs trees. The modern bony pike and the cat-fish of India are able also to use their swim-bladders as auxiliary breathing organs. They occasionally come to the surface of the water and gulp in great mouthfuls of air. Then there are the mud fishes, so-called from their habit of burrowing and burying themselves in the mud during the dry seasons, when the waters in which they live evaporate and disappear. They are able thus to survive through long periods of drought. Many of them have been transported without injury or inconvenience to themselves from one part of the globe to another wrapped merely in a coating of mud.

They stand midway between the ordinary water-breathing fishes and the Dipnoi. Their air-bladders are seen to be connected with their gullets by a permanent open duct, and they also have an unusual blood supply, by means of which these organs are able to act as incipient lungs. From these to the Dipnoi, or lung-fish proper, the transition is easy. In the Dipnoi we find the air-bladder is much more highly developed than in the mud fishes. Their nostrils, too, open directly into the mouth cavity, which is not the case with any other kind of fish. They also possess a pulmonary artery and vein, and the auricle of the heart is partially divided into two compartments, thus foreshadowing the two auricles characteristic of the heart of the Amphibia and the higher animals.

With such evidence of progressive differentiation before us, then, it is not possible to doubt that this was the manner in which the evolution of the lung-breathing vertebrates came about. We know that the Cambrian, Silurian and Devonian seas, and especially the latter, teemed with fish life. This was the age, par excellence, of fishes. The struggle, therefore of marine existence must have been exceedingly fierce and keen. The fish of the marginal zones would be forced into the adjacent swamps and marshes, of which there were many in those days, and such forms as were capable of making response to these new conditions of life would slowly adapt themselves, first to a marshy existence—such as has the present-day siren or mud-eel, with its single pair of short limbs and permanent external gills, or that most primitive of the modern salamanders, the mud-puppy or water-dog, as it is variously called — and later, under still further pressure from behind, to life on the land.

The period of transition probably occupied thousands of years, beginning in Upper Silurian times and continuing through the Devonian into the Carboniferous age. That such was the course of evolution we cannot doubt, for many of the major steps and stages have been stereotyped for us as we have seen, in those animals in which the transitional phases have become fixed and hereditary, such as the Dipnoi, the siren and the mud-puppy.

From observation of these we should expect the primordial Amphibians to resemble closely the commonest fish-like forms. This is exactly what the palæontological evidence reveals to us. The earliest known fossil Amphibians were those of small-headed, long-bodied, short-limbed, tail-propelling types, represented by the mud-eel, newts and salamanders of today. Confirming and reinforcing these facts in the most

indubitable manner is the evidence from embryology. Here in the individual life-history of the modern amphibian we see a fairly complete recapitulation of the successive evolutionary phases displayed by the intermediate forms which bridge over the gap between the lung-breathing amphibian and the gill-breathing fish. Let us dwell upon these phases for a moment; they are very instructive. All the Amphibia normally lay their eggs in water. These hatch out there as do the eggs of the fishes. The young take on a purely fish-like existence, breathing wholly through gills till they reach a stage of development when their amphibian metamorphosis takes place. They now gradually shed their fish-like characters and become lung-breathing, terrestrial animals.

That the palæozoic fishes possessed this power of adaptive response to changed conditions of life, we here suppose them to have shown, we cannot for a moment doubt. It is a common attribute of all organic forms, and that the same responsive power was passed on to their amphibian descendents becomes abundantly clear from the extraordinary adaptive responses to environmental changes which some species of frogs, toads and salamanders make today.

Normally these creatures return to the water—the ancestral habitat—for purposes of reproduction. This inherited habit is so deep-seated in their constitution that they depart from it only under very abnormal conditions. Let us deal with the habits of the frogs first. Not all of these live the same kind of lives. Some are water-frogs and rarely take to the land. Others of the land species have learned to climb and live in trees. These are the tree-frogs, and they return to water only for breeding purposes. Other of the land frogs do the same. But there are some species which never return to the ancestral element even for reproductive reasons. They have become to all intents and purposes land animals. One of these, found in Chile, and known as Darwin's frog, never lays its eggs in water. They are stored away by the male in his croaking-sacs, from which the young later emerge as fully-formed frogs, literally jumping out of their parent's mouth.

Still another method of depositing and hatching its eggs is that adopted by one of the South American tree-frogs (Nototrema). This creature carries its eggs in a pouch on its back until the young frogs are ready to leap out.

A still more novel method of hatching its eggs is that followed by the Surinam toad. This animal presses its eggs by the help of the male parent into little pockets in the skin of its back, from out of which the little toads eventually emerge fully formed.

That all these batrachians, or rather their ancestors, once brought their offspring to maturity in the ordinary way as young fish or tadpoles in a watery environment, becomes clear from the interesting and significant fact that we sometimes find the eggs of the tree-frog species developing into tadpoles, thus showing a reversion to the earlier ancestral mode of development.

We can only regard the methods of rearing their young displayed by these three batrachians as adaptive responses to alterations in their environment. There seems no other reasonable way of explaining changes of function and habit so deep-seated and long-inherited as these. The same conclusion is again forced upon us when we observe what takes place among the salamanders, creatures of lizard-like characters. Here we have even a more remarkable and decisive instance of the influence, external conditions may exercise upon the lives and habits of animals.

There are two distinct species of this kind of batrachian, Salamander atra and S. maculosa. The present habitat of the former is a dry alpine region of relatively low temperature.

The latter occupies a low region with plenty of water and a high temperature In the dry region of S. atra. we find the eggs are hatched out as land animals; there is no fish or tadpole stage.

In the wet region of S. maculosa, on the other hand, the embryos are less developed when hatched; they possess gills like fish, and complete their larval development as aquatic animals. Thus it becomes clear that each species adapts itself to its immediate environment. To illustrate how strong and active this adaptive power of a living organism is, we have only to transport S. atra to a wet region with a relatively high temperature, to see it return to the ancestral mode of developing its young. Under the new conditions of life, imposed by the change of location, it straightway deposits its eggs in a less advanced state; with the consequence that the young hatch out in the gill-bearing stage and complete their development in the water in the same manner as do the young of S. maculosa. Conversely, if we place S. maculosa under alpine conditions its eggs are not deposited until the embryos have passed beyond the gill-bearing stage, with the result that they are born as lung-breathing, land animals.

These instances of modification of habits and functions are interesting not only as illustrations of the evolutionary history of the batrachia themselves, but also as instances of that adaptive power which is the common possession of every organic form throughout the whole life-realm. So much for the evolution of the lungs of the Amphibia, but what of their pentadactylic limbs? How did these arise?

Gegenbaur, one of the most distinguished of the German comparative anatomists of the last century, held and taught that the prototype of the limbs of the land vertebrates was to be found in the fins of the modern lung-fish of Australia—the Ceratodus. This view was accepted by biologists generally till a second and different one was later put forward by a British scientist, Francis Balfour, a professor of animal morphology, at the University of Cambridge. His view is known as "The Lateral Fin Hypothesis." Under this conception the origin of the limbs of the land vertebrates is based upon certain similarities in the paired and the unpaired fins of certain fishes. It is supposed that the paired fins arose by the persistence of parts of what was originally a continuous fin along each side of the body.

Balfour attacked the problem from the embryological standpoint. He found that the pectoral (fore) and pelvic (hind) fin rudiments were in the earlier embryonic life of the fish actually continuous with one another, and he drew from this discovery the conclusion that the limbs of the Amphibia, and consequently of all the land vertebrates, were remnants of these original, continuous fins.

These two views shared the biological field between them until some more direct evidence later came in from palæontological sources. This gave rise to a third view which more or less superseded the other two. The discovery of primitive types of the fringe-finned, ganoid fish led to the belief, especially in palæontological quarters, that this class of fish rather than the Dipnoi represented the ancestral line of the Amphibia, and their fins the source of the Amphibian limbs.

The fins of these ganoids, with their spreading, fan-like fringe or dermal rays at their extremities, were seen to be stiffened and strengthened by cartilaginous rods. From these, by modifications—induced by adaptive responses to the change from existence in a littoral zone to one in a muddy, shore zone—there resulted ultimately the articulated, five-digited limbs of the Amphibia. Such a radical transformation presupposes, of course, a long stretch of geologic time, as in the kindred case of the

evolution of the lungs. This is readily found in the period stretching from Upper Silurian to Carboniferous times.

Regarding this view as possibly setting forth the actual mode of origin of the vertebrate limbs, it is not difficult to see how this fan-like fringe at the end of the fin could act like an incipient, flat, spreading foot to propel its owner over muddy surfaces. Indeed, the evidence in favor of this view as set forth by Prof. Osborn, one of America's foremost authorities on Palæontology, in 1918, seemed to have definitely settled for all time the question of the direct line of descent of the Amphibia, and the mode of origin of their limbs.

More recently, however, a new view has been presented by Prof. Graham Kerr, of Glasgow. This is known as "The External Gill Hypothesis," and is, in a measure, a return to the earlier views of Gegenbaur under a modified form. Both views are "gill-septa" hypotheses, one taking the surface septa and the other the external septa as the basis or starting points of their contentions. Kerr is an embryologist and naturally regards the problem under its embryological aspects. In his studies of archaic vertebrates he gave particular attention to the breathing organs of these creatures. These organs are the gill arches which stand well out beyond the surface of the body and are known as "external gills." They also possess muscles by which they can be moved backwards and forwards.

We find these external gills well represented in the axolotl, a tailed amphibian of the newt or lizard type, found today in Mexico. These creatures leave the tadpole stage of their existence seemingly very reluctantly; at times retaining their external gills throughout life. In appearance they resemble gigantic tadpoles some six to nine inches long, with gill-tufts stretching out some distance beyond the side of their necks. Kerr found similar structures in several genera of aquatic vertebrates, notably in the lung-fishes Lepidosiren and Protopterus; from which fact he drew the conclusion that these external gill-septa form a more primitive system of breathing than the system observed by Gegenbaur in Ceratodus of Australia, whose gill-septa are flush with its body.

He claims that the physiological possibility of external gills evolving into limbs must be admitted without cavil. Limbs, he points out, are essentially projections of the body for support and propulsion. The balancers of Urodeles show us a form of external gill actually converted into simple leg-like supports; and observation of the flicking movements of the external gills in the live animal, makes it fairly clear how they could be transformed into organs of propulsion.

According to this view the limbs of the land vertebrates were in their earliest phase styliform structures for pushing against solid objects. He further takes the view, in common with the majority of biologists, that the primitive vertebrates, although aquatic in origin were not pelagic, but marginal animals. He regards the pelagic environment as the most homogeneous of all possible environments, the tendency of which is to check up or hinder variation. The marginal zone, on the contrary, is the natural nursery or forcing ground for new types; and he locates in this zone the home and seat of vertebrate evolution. He also takes occasion to point out that here we may perceive something of the process by which the limbs of the land animals arose by modification from these external gill-septa, by observing the young Lepidosiren today as he clambers about on his styli-form, hind limbs. We see the points of them bent over by the weight of the fish like a foot and other parts of them like incipient ankle- and knee-joints.

Which of these two last views, both seemingly equally supported by material evidence, will ultimately prevail, or whether others still more

plausible, will hereafter be put forward to take their place, remains yet to be seen. One thing, however, is quite clear and that is that these limbs, whatever their source, have been evolved, like the pulmonary organs of the Amphibia, from some earlier organ, by a slow and gradual transformation.

The question of whether it was by way of the gills or the fins is after all a relatively minor one. The main point is that nobody who takes all the facts of this transformation into account, can have any doubt that the limbs of the Amphibia arose originally in some such manner as is suggested by these hypotheses.

We actually see the sounds of the lung-fish undergoing transformation under our eyes today. We cannot, therefore, consistently doubt that the limbs of these transitionary forms arose in some similar way. What precisely this way was, we may, with our rapidly increasing knowledge of physiological processes and of primitive, fossil forms, hope to learn, beyond contention or doubt, before long.

CHAPTER XVII.

The Reptiles

IN the last chapter we traced the evolution of the Amphibians, the earliest of the land vertebrates, from some preceding fish-like form, and saw that, although there still remains some difference of opinion among evolutionists concerning the precise line of descent of these animals, whether they came from this or that species of fish, no doubt at all exists in their minds concerning the fact of this picine descent.

The early aquatic phase of life these intermediate forms normally pass through, and their possession during this period of fish-like gills or water-breathing organs, placed their origin beyond doubt or question. The remarkable metamorphosis these creatures undergo at the close of their larval life today is, perhaps, the best and clearest instance that can be offered of the truth of the biogenetic law, that the early life-history of the individual (ontogeny) is in large measure a recapitulation of the life-history of the species to which it belongs (phylogeny).

The Amphibia during the first three months of their existence may be said literally to climb up their own ancestral tree, and no reasonable explanation of these recapitulative phases can be given apart from the doctrine of evolution. Apply this principle and the life-cycle of the frog or newt, with the deep-seated transformations manifested therein, becomes clear and illuminating. Disregard it and one is faced with an inexplicable problem. No "Fundamentalist" teaching can solve it.

Taken at one period of their existence the Amphibia are gill-breathing fish that cannot live out of the water. At a later period they are seen to be lung-breathing animals that cannot exist in and under water for any length of time any more than we can ourselves. If, as the anti-evolutionist would have us believe, they were created out of hand in the beginning, in which of the two phases of their lives were they brought into being? As fish or as land animals? And how did the fish-form become the land-form or vice versa, if there be no evolutionary process in nature?

Between the Amphibia and the next higher class of land vertebrates, the Reptilia, the gap is slight. They merge almost insensibly into each other. During the Carboniferous, and the earlier phases of the succeeding Permian period, important changes of the land surfaces took place. The shore zones underwent elevation which brought about a consequent recession of the sea. This resulted in a more varied habitat for the Amphibia which apparently called forth new adaptive responses on their part; for we find many new forms now arising. The earliest fossil Amphibians known to us were characterized by layers of fish-like scales on the surface of their bodies, which we can only suppose were inheritances from their picine ancestors. This feature disappears in the newer types, and we find the same variety of forms arising among them as were later to appear among and characterize the Reptilia. Thus we have the Salamander-like **Eumicrerpeton**, the eel-shaped Ptyonius with its single pair of short limbs, and the strange-looking **Diplocaulus** whose solid, broad, bony skull had the appearance of a gigantic, triangular arrow-head attached to

the spinal column. There were also alligator-like forms and others with protective armature and enormous spines.

The Amphibia reached their greatest development during the Permian and early Triassic periods, some of them during the latter period attaining immense proportions. One of these, known as the Mastodonsaurus on account of its great size, had a skull four feet in length and a body nearly 20 feet long. In general appearance it resembled the present-day Salamander. Thus the Salamander type is seen to be one of the most persistent of all the Amphibian forms. It is one of the earliest types known to us and is also one of the most interesting and characteristic forms of the modern Amphibia.

Another of these huge late Permian forms was the Eryops, a crocodile-like creature with massive head, short, strong limbs and a long, powerful tail.

With the closing of the Permian and the on-coming of the succeeding Triassic period, the golden age of the Amphibia passes away to give place to that of the more highly-organized Reptilia. From this time onward the evidence of their presence grows less and less. In the Cretaceous only a few fossil specimens of the small Salamander type are found, after which the links between the modern Amphibia and the more ancient forms—apart from the Salamanders—are wholly absent. The day of the Amphibia is over.

But so insensibly are the Amphibians of the Permian seen to merge into the Reptiles that it is often quite difficult to determine from the external appearance of the fossil alone whether it belongs to the Amphibia or to the Reptilia. There is, however, one important structural difference between the two great classes. In the Amphibia articulation of the skull with the back-bone is effected by means of two knuckle-like condyles or bony projections. In the reptiles, as in the birds which evolve from them, there is only one of these condyles. This fundamental, anatomical difference enables us to distinguish between one fossil form and another from these geological periods, and feel certain which we are dealing with when these parts of the skeleton are present. Another characteristic difference between the two classes is that the Reptiles are exclusively air-breathing, lunged-animals. They never rear their young in the water as we have seen the Amphibia normally still do. Yet their genetic relation to and descent from the Amphibia is plainly evidenced by the presence of gill-slits and traces of the gills themselves in the embryos of certain of the Reptilia.

Our earliest knowledge of the Reptiles dates from the Permian. We know of none before this period. The most primitive forms known to us are termed cotylosaurs. These differ from their later kindred by the possession of solid, roof-like skulls. They closely resemble in this respect the solid-headed kind of Amphibia known as the Stagocephalia from which, Osborn thinks, they are derived. They are a kind of animal intermediate between the Amphibia and the Reptilia proper.

The rise and distribution of the Reptiles would appear from the fossil evidence to have been rapid, geologically speaking, when once they had been evolved. Their range of form and structure was wide and varied, and their adaptive responses to their environment very remarkable. We find them living under almost every possible condition of life. There were aquatic, paddle-footed, free-swimming forms like Limnocelis, which propelled itself by means of its long tail; semi-aquatic, short-tailed forms such as Labidosaurus. There were marginal or marshland forms, insectivorous or carnivorous in their habits. Terrestrial, lacustrine, fluviatile and aerial forms both, herbivorous and carnivorous; some being active during the

day and others during the night. Some of the terrestrial forms, the Dinosaurs, were of fearsome aspect, massive, predaceous creatures with sharp dog-like teeth. Other of the gigantic terrestrial forms were herbaceous in habit, feeding upon the leaves and shoots of trees. Three of these great Sauropods, as they are termed, namely Diplodocus, Camarasaurus and Brachyosarus, attained incredible proportions having bodies 100 feet or more in length most of which, however, was composed of their huge necks and enormous tails. They could browse with ease upon trees 20 to 25 feet high.

Taking the Reptilia as a whole they comprise no less than eighteen distinct orders which are again subdivided into a great number of families, genera and species. These eighteen orders sprang originally from some common Amphibian ancestor; and though we cannot yet positively assert what this common ancestral form was, there are good grounds for thinking that it was of the Varanops type, a primitive, lizard-like creature resembling in general appearance the modern monitor lizard Varanus. It had a long tail and four limbs of equal proportions each carrying five digits. Its structure was such that in the opinion of Osborn it could easily have been the prototype from which all the eighteen orders of the Reptilia might have sprung.

The Reptilian period extends from the Permian, the closing phase of the Palæozoic, through the whole Mesozoic or middle-life era to the Eocene, the earliest phase of the Cainozoic or modern-life era—a period of from 15,000,000 to 20,000,000 years.

The Reptiles are the dominant life-forms of the Mesozoic era. Of the eighteen orders that came into existence five only apparently survived into the Tertiary period. The descendents of these are represented by the present-day turtles, tuateras (the giant lizards of New Zealand), snakes, lizards and crocodiles. The passing of the Reptiles is generally attributed to the high degree of specialization to which most of them had attained, and their consequent lack of ability to respond to the very considerable climatic and other changes which marked the close of the Mesozoic era and ushered in the Tertiary period.

Our study of the life-realm has made it very clear that while high specialization aids an organism in the struggle for existence, it also carries with it the doom of early extinction should radical changes in its life-conditions take place; its very specialization rendering it unable to make the necessary adaptive responses to these changes.

Two classes of Reptiles stand out in particular from the rest as having high evolutionary interest for us. These are the Theromopha or beast-like forms, and the Pterosaurs or flying-forms. Of the former the Cynodont, a creature with dog-like teeth, and the Therodont, a creature with wild-beast-like teeth are typical forms. These pro-mammals, as they are called, are now generally regarded by palæontologists as the forerunners of the animals which were later to succeed and supplant the Reptiles. They were marked-off from the other forms by their much more highly-developed and sturdier limbs by which they were enabled to get over the ground more rapidly, and by the higher adaptability of their teeth. Speedy specialization of the teeth is seen to be one of the marked features of mammalian development, just as a lack of it is characteristic of the Reptiles generally.

Before the geological record had revealed these pro-mammalian forms to us it was commonly thought that the direct line of descent of the later mammals was through some amphibian ancestor, so difficult was it to connect the Mammals with the Reptiles, as they were then known to us, on anatomical grounds alone. The

fortunate discovery of these fossils not only removes this difficulty but also at the time affords encouragement to hope that other missing links will likewise in time be brought to light; for while anatomy and embryology each yields valuable evidence to the evolutionist, it cannot carry with it the same degree of certainty as the more direct evidence of palæontology is able to do.

The Pterosaurs or flying-reptiles constitute one of the most interesting of the many strange reptilian forms. In size they ranged from creatures not much bigger than a sparrow to forms with a spread of wing greater than that of any bird of today. They are not to be regarded as the direct ancestors of the feathered birds later to appear. They are merely flying reptiles, and their mode of flight, by means of bat-like wings, is believed to have been a kind of soaring or gliding motion from a higher to a lower level. Their chief interest for the evolutionist lies in the evidence they afford of the wide adaptive radiation of the Reptilia. We learn from these Pterosaurs that the Reptiles had conquered the air as well as the land and the sea and that in this way they foreshadowed the birds.

The origin of the feathered, true birds must be sought, it is believed, elsewhere, in some small, lizard-like reptile whose habits of locomotion were largely bipedal, and which had been forced to adopt in large measure an arboreal existence to escape its many enemies. We gather this from some of the peculiar characters displayed by the earliest of the birds known to us—the Archæopteryx. The wings of this creature were tipped with finger-like claws which —on the analogy of the tree-climbing habits of the present-day young of the hoatzin, a strange species of South American bird—it probably used for climbing purposes. From this habit of living largely in trees a modification of its limbs would have been brought about something after the manner of that seen in the flying-squirrel of today. Exactly what lines this modification followed we have at present no means of knowing. Fossils of the earliest birds are yet very rare.

Our chief authorities on the evolution of birds and their wings hold two distinct views as to the origin of the latter. One, known as the "pair-wing" theory, deduced from the earlier studies of the wing of Archæopteryx. This regards the long, primary feathers upon the fore-limb, and also those at the sides of the tail, as arising from modification of the earlier reptilian scales. The other, known as the "four-wing theory," more recently put forward by Beebe, is based principally on the presence of large feathers on the thighs of the embryos of modern birds. It accounts for the later disappearance of the hind-leg wings by increasing non-use as the flight function of the fore-limbs and the steering-function of the tail became more and more developed and specialized. As our knowledge of the primitive fossil birds increases we may be able to determine which of these two views is the more correct one.

But though we are as yet uncertain of the precise mode of evolution of the wings of the bird, no doubt at all exists as to the reptilian origin of the birds themselves. The earliest fossil birds known to us possess far too many striking reptilian characters for us to entertain any doubt on this head. The gradual approach, too, from the early reptilian forms, all of which seemed to have possessed teeth, to the present-day forms, as revealed by palæontological evidence, also strongly confirms us in this view. And even the modern birds, highly modified and specialized as they are, still plainly show many marked reptilian characters. One of these is the way in which the skull is articulated with the spine. It is identical with that among the reptiles, both birds and reptiles possessing equally but one condyle. This is a very important homology and carries

much significance with it. Both, too, are egg-layers.

Another specific character showing the close relationship between the two forms is the third eye-lid or "nictitating membrane" common to bird and reptile alike; only in the former, as we might expect under the evolutionary principle, the moving mechanism of this lid shows an advance upon that in the reptiles similar to that seen in their brains.

It is not without significance, too, that certain birds of today never sit upon their eggs to hatch them, but bury them in a mound composed of vegetable matter and earth, and leave them there for the chemical heat generated by the decaying matter to do the hatching. The alligator, one of the present day amphibians, treats its eggs in just this way. This significance is not lessened when we remember that a group of birds which follow this practice is found in Australia, the region where the evolutionary process has been less active than elsewhere, and where the most archaic birds and mammals are to be found today. It is quite possible these birds have practised this reptilian way of hatching their eggs from Eocene times downwards.

The young of these birds have interesting characters too, which speak eloquently of their ancestral history. While in the egg the first downy covering is shed and a second and more complicated generation of down feathers appears, together with the wing quills. They are ready for flight at once when hatched. There is much significance in this. It furnishes another example of the adaptive power of life-forms, and recalls the instances of the ready-born frogs and salamanders, which skipped the tadpole stage.

That the feathers of the birds are merely modified scales has been made quite clear by some recent researches upon the leg-feathers in the ostrich by Dr. Duerden of the Rhodes University of South Africa. He has been able to show that where the minute scales of the leg pass into the feathered part above, they bear elementary feathers at the time of hatching. The scale and the feather are associated together as if of one and the same structure, the latter being clearly an outgrowth of the former. His observations in this direction have led him to the conclusion that we can entertain no doubt at all about the genetic relationship of the birds and reptiles.

The palæontological record is thus seen to be strongly supported by these supplementary lines of evidence. We can have no doubt, therefore, of the reptilian origin of birds.

CHAPTER XVIII.

The Mammals

IN our survey thus far of the evolutionary course taken by the life forms on our globe, we have had occasion at times to speak of this or that geological period or life-era, taking it rather for granted that all our readers were familiar with these terms. Before going further it may not be amiss if we devote a portion of this article to a brief consideration of these time divisions and familiarize our minds with their sequences. By so doing we shall get a better and clearer view of the general onward march of life; and shall be able to perceive how insensibly one life order has, on the whole, merged into and been succeeded by another; and how continuous and unbroken has been the stream of life from the beginning down to our own day.

The geological record is usually divided into five great "eras" or primary life-divisions. These are subdivided into "periods," and some of these again into "epochs." The first and remotest of these eras is called the Archæozoic or earliest life era (from the Greek arche beginning, and zoe, life.) The second is called the Proterozoic or early life era (from the Greek proteros, early, and zoe, life.) These two together constitute what is known as the Pre-Cambrian age. We can gather very little knowledge of the life-forms that existed in those far-off times on account of the wide-spread alteration and deformation of the rocks of this age. Pre-Cambrian fossils are exceedingly scanty. Heat, pressure and other crustal disturbances have obliterated or destroyed most of them. It is thought that the time occupied by these two Pre-Cambrian eras was longer than all the succeeding ones put together. It can only be very vaguely estimated by tens, or more probably by hundreds, of millions of years.

The next, or third division, is known as the Palæozoic or ancient life era (from the Greek palaios, ancient; and zoe, life.) This era is usually divided into six "periods" called respectively: Cambrian, Ordovician, Silurian, Devonian, Carboniferous and Permian. The last named is regarded by some geologists as one of the subdivisions of the Carboniferous, and not treated as a separate period. But we need not consider such nice distinctions as these in this inquiry.

The characteristic life-forms of the first three of these Palæozoic periods —the Cambrian, Ordovician and Silurian—are the animals without backbones. It is the age, par excellence, of the invertebrates. In the three later periods—the Devonian, Carboniferous and Permian—the early vertebrates—the Fish, the Amphibians and the primitive Reptiles—are the characteristic life-forms; the Devonian being particularly distinguished as the "Ages of Fishes," so predominant were these forms during that period. The Palæozoic rocks reached a great thickness, estimated to be not less than 100,000 feet. One system alone — the Cambrian — attained a maximum depth in the Canadian Rockies of 40,000 feet, or between seven and eight miles. The duration of the Palæozoic era was thus very considerable, second only to that of Pre-Cambrian time. It far exceeded the two subsequent eras put together; and would appear to have not been less than fifty millions of years in all.

The Mesozoic or middle-life era

(from the Greek mesos, middle; and zoe, life) is usually divided into three separate periods, namely: the Triassic, Jurassic and Cretaceous. The duration of the Mesozoic is estimated at from ten to twelve millions of years. Throughout this era the Reptiles are the dominant life-forms. The Mesozoic is pre-eminently the "Age of Reptiles." We dealt with them in the last article.

The fifth and latest life-era is the Cainozoic or recent-life era (from the Greek kainos, recent; and zoe, life). The dominant life-forms of this era are the mammals. The Cainozoic is pre-eminently the "Age of Mammals." Its duration is variously estimated at from three to five millions of years. This is the era in which we ourselves are living. It is commonly divided into two periods known as the Tertiary and the Quaternary; the former occupying from three to four millions of years and the latter from 500,000 to one million of years. These periods are again subdivided into "epochs," the Tertiary having four and the Quaternary two, of these. The terms by which these epochs are known indicate the greater or less number of the present-day life-forms found in each of them. These terms in the Tertiary (reading upwards) are:

(1) The Eocene, the epoch of the dawn of the present-day or recent life-forms (from the Greek eos, dawn; and kainos, recent.)

(2) The Oligocene, the epoch when only a few of the present-day or recent life-forms had appeared (from the Greek oligos, few or little; and kainos, recent.)

(3.) The Miocene. the epoch when less of the recent life-forms appear than in the epoch following (from the Greek meion, less; and kainos, recent.)

(4) The Pliocene, the epoch when more of the recent life-forms are found (from the Greek pleion, more; and kainos, recent).

In the Quaternary they are:

(1) The Pleistocene, the epoch in which most of the recent life-forms appear (from the Greek pleistos, most; and kainos, recent.)

This epoch takes in, and is generally regarded as synchronous with, the Glacial Age.

(2) Holocene, the epoch when all the recent life-forms appear (from the Greek olos, all, the whole; and kainos, recent).

These useful, connotive terms were given to the divisions of the Tertiary and Quarternary periods by Lyell, the most distinguished of the British geologists of the last century. They mark, as has been said, the gradual evolution and appearance of the modern forms as represented by that common geological time-standard—the Molluscs.

With these time divisions and life-eras more clearly before us we may now enter upon our consideration of the evolutionary history of the latest and most highly-organized of all the life-forms—the Mammals.

As far as we can gather from the palæontological evidence the reptilian age came to a relatively abrupt termination. There is a great biological break between the closing phase of the Mesozoic era and the opening phase of the succeeding Cainozoic. Whole chapters in the life-history of the Cretaceous reptiles and Eocene mammals are missing; and what they contained we have to discover as best we may by inference. Geologists tell us this period was one of wide-spread crustal movement and disturbance, of mountain-forming on a large scale, with consequent alteration in climatic and other environmental conditions. By the time the Eocene epoch was well advanced, thirteen of the known eighteen orders of the Mesozoic reptiles had entirely disappeared from the face of the earth and their place had been taken by the Eocene mammals. The toothed birds, characteristic of the Cretaceous, had also disappeared along with the fierce and bulky dinosaurs, and we find in their place new forms more nearly akin to those of the present day. A mighty transformation is everywhere apparent; a new world, peo-

pled with new forms of life, bursts as it were suddenly upon our view.

This biological break, with its many missing links, makes it very difficult for us to follow the earliest phases of mammalian evolution; for while palæontologists do not for a moment doubt the reptilian descent of the mammals, the tracing of the direct lines of this descent presents some difficulties. Theoretically speaking the reptilian affinities of the mammals are established beyond question by the present existence in Australia and New Guinea of intermediate, connecting forms. We find there a line of primitively-formed egg-laying mammals, of which the strange duck-mole or Platypus is the best known type. This anomalous creature links up the two life-orders in a truly remarkable and highly suggestive way. Darwin called it "a living fossil," and so it would appear to be. It is as much a reptile as a mammal. It lays real eggs like the Mesozoic and most of the modern reptiles. It has also a common, single outlet for its excreta, and likewise possesses other characteristic, reptilian features; but unlike the reptiles it suckles its young like a mammal, except that it has no "mammæ" or milk organs proper. In place of these it has a number of punctures on its breast from which a fatty liquid oozes, to be licked off by the newly-hatched young.

It is thus seen to be neither truly reptile nor truly mammal, but plainly an intermediate or transitional form standing fairly midway between the two life-orders. We could hardly ask for better evidence of the genetic relationship of the two classes than is furnished by these anomalous, stereotyped forms that have come down to us little changed in character from Mesozoic times.

We know, too, that numbers of such ambiguous, transitional forms, as the Australian duck-mole and the spiny ant-eater, must have existed in those days, for many of their fossils have been recovered. There is one well-known form in particular—Tritylodon—which has been made a kind of shuttlecock by zoologists who have studied it, so indeterminate are its characters and so difficult is it to decide whether it should be classed as a reptile or a mammal. And we cannot doubt that if all these ambiguous, indeterminate forms were known to us it would often be impossible to say definitely to which group many of them belonged.

With these facts in our mind and with these intermediate connecting fossil and living forms before us, it is not possible to doubt the genetic descent, by modification, of the mammals from the earlier reptiles.

Accepting, then, as biologists everywhere do, this descent as an incontrovertible and well-ascertained fact, what may we gather concerning the course mammalian evolution has taken? Can we learn anything of the stages through which it has passed since the period of Tritylodon of Triassic times? Let us see.

In our survey of the rise and adaptive radiation of the Reptiles, we saw that some of the early Permian forms were characterized by mammalian features. It was stated, too, that these Theromopha were generally regarded by palæontologists as the original source or ancestral stock from which the mammals are descended. What became of these Permian pro-mammals? What do we know of their subsequent history?

We know they diverged into various groups more or less distinct from one another, some being herbivorous and others carnivorous in habit and that they spread over three continents. If we are to judge by the evidence of fossils alone they would seem to have become extinct before the Mesozoic was well advanced, for no fossilized forms are found after the advent of the Jurassic. To what cause can we attribute this seeming extinction? We know they survived the severe changes which brought the Palæozoic to a close and ushered in the Mesozoic. It is possible that rapid development

resulted in such high specialization as to unfit them for the new condition of things and competition with the better-adapted reptiles of the Jurassic, and so brought about their end in this way. This is the common view taken regarding their disappearance. But it by no means necessarily follows that because they seem to disappear in the Jurassic they became extinct and left no progeny to succeed them.

Practically all our knowledge of the life-forms of the Mesozoic era is drawn from fossils obtained from swamp, marsh, delta and lagoon deposits. We know little or nothing of the life-forms that may have occupied the uplands of that era. It is quite possible that mammalian life-forms may have spread to, and existed in such regions throughout the whole Mesozoic. Indeed, we are almost driven to postulate some such condition of things when all the facts are taken into consideration; for in the very earliest of the Tertiary upland deposits there is revealed to us a wonderfully rich and highly-varied mammalian fauna.

Whence came these? It does not seem possible to derive them from the tiny very generalized mammals known from fossil evidence to have been contemporaneous with the Jurassic and Cretaceous Reptiles. It is far more reasonable to regard these numerous and highly differentiated forms as the direct descendents of a Mesozoic fauna that had persisted from Permian times, the period of the advent of the Theromorpha or pro-mammals. The fact that we know of no upland fossil-bearing deposits belonging to the Mesozoic is no argument against their existence. Such deposits may yet be discovered if they have not been, as is very possible, wholly wiped out by erosion, or by those crustal disturbances we know to have occurred at the close of the Mesozoic and the beginning of the Cainozoic, when the Rockies and the Alps came into existence.

Another view has been put forward, and is now held by some of our palæontologists, to account for the seemingly sudden appearance of these early Tertiary mammals. This supposes the existence, in some portion of the globe, which had been cut off and isolated from the rest, early in Mesozoic times by impassable barriers, of a mammalian fauna which flourished there throughout the whole Mesozoic era. These barriers, it is thought, were broken down by the secular changes which ushered in the Cainozoic era; and the new conditions of life being favorable to this liberated fauna, it rapidly spread over the world and took the place of the now extinct reptiles.

Both of these views are quite reasonable and the second receives strong support from the analogy of the condition and long isolation of the fauna of Australasia. Here both the fauna and flora, by the isolation of this region from the rest of the world since Mesozoic times down to our own day, and by the absence of competition with other life-forms, have retained in large measure their primitive characters, while at the same time evolving and becoming specialized along their own peculiar lines.

In their general physical characters the early Eocene mammals were in many ways very similar to the present-day mammals of Australia and New Zealand. They pointed most clearly to a Mesozoic ancestry; and as a class they became extinct by the beginning of the Oligocene epoch. Some of them were pouch-bearing animals similar to those of Australasia. Others of them were true placental mammals though of a primitive and lowly-organized type. We learn from their teeth that some of them were rodents, while others were fruit-eaters and still others insectivors.

The most conspicuous of these Eocene mammals were those known as the Amblypoda (Greek amblus, blunt; and pous, foot). Some of these, notably Eobasileus, were of immense proportions and highly suggestive of

the bulky rhinoceros and hippopotamus which were later to appear. Their heads were the most peculiar features about them. Upon these they carried three pairs of knob-like horns; one pair over the nostrils, a second and larger pair over the eyes, and the third and largest pair behind the ears. They also possessed a pair of dependent canine teeth closely resembling those of the sabre-tooth tiger also to appear later. The brain of these bulky, slow-moving animals was very small in proportion to their size; not bigger than that of a dog, though some of them must have weighed as much as two tons. The structure of the brain, too, was of a low order, resembling that of the reptiles. This small size and poor development of the brain may have contributed largely to bring about their extinction; for by the close of the Eocene they had all disappeared. They would seem to have lacked the ability to successfully compete with their more highly-endowed rivals in the life-struggle.

Of these early Cainozoic mammals it would seem that only one class could have been the ancestors of the present-day mammals. This was probably one of the small insectivors.

As early as Huxley's time it was pointed out that we must look for the ancestry of the modern mammals in some animal of the insect-eating type. Such a line of ancestors is strongly suggested by what we know of the teeth of the mammals. Modern research points in the same direction, to some such insectivor as the present-day, little tree-shrew. Not only our own remote ancestors, but also those of the other mammals would seem to have been tree-climbers. Arboreal habits are plainly indicated in the limb-grasping adaptions of many of the present-day mammals. Our highest authorities on these matters are now largely a unit in tracing the descent of the modern mammals from some insectivorous ancestor, which passed much of its existence in trees. If, therefore, any of the early Eocene mammals are to be regarded as the ancestral forms from which the modern mammals have sprung, it must be one of the little, tree-loving insectivors.

From such an ancestor, Osborn, with his wide knowledge of Palæontology and Morphology finds no difficulty in deriving the whole ten major groups into which he divides the modern mammals, namely:

(1) Whales, (2) Seals (marine carnivores), (3) Carnivores, (terrestrial), (4) Insectivores, (5) Bats, (6) Hoofed animals, (7) Manatees (Sirenia or Sea-Cows), (8) Rodents, (9) Edenates (toothless animals such as the Ant-eater), (10) Primates, including Lemurs, Monkeys, Apes and Man.

From the highly-specialized and widely-differentiated mammals of today to a little tree-climbing insectivor like the shrew, will seem to the average lay mind, uninstructed in the principles of morphology, a far cry indeed. The gap will appear to him too great to be bridged. Yet each year, with its fresh accessions of palæontological evidence, brings confirmation of this genetic relationship, and the gap is steadily growing narrower with every new discovery. And investigators, like Sir Ray Lankester in England, and Professor Fairfield Osborn in America who have given a life-time of study to the tracing out of these relationships and who have seen link after link in the chain of evidence come to light, are very sanguine that science will be able, in the near future, to demonstrate, by the help of discoveries yet to be made, this descent and common origin to the satisfaction of any intelligent person who will view the evidence with open mind.

Already the ancestral history of many of the present-day mammals has been fairly-well worked out. Notably that of the horse, the camel, and the elephant. We are able to trace back the lineage of these animals by means of intermediate forms to early Tertiary times. The ancestral history of the horse has, perhaps, been retraced with the most detail, and a brief review of the palæontological ev-

idence, by which the evolutionary transformations of this well-known animal have been followed step by step will be very enlightening. It will also, incidentally, help us to understand how the modern mammals could have been derived from earlier and less-specialized forms, and these again from some common ancestor of more generalized character.

This review we will take up in the next chapter.

CHAPTER XIX.

The Horse, the Marine Mammals and the Primates

IN the last chapter it was stated that modern research into the phylogeny or ancestral history of the present-day mammals pointed strongly to some small, generalized tree-climbing insectivor, not greatly unlike, in general characters, the modern, little tree-shrew, as the probable ancestral source from which they might all, in early Tertiary times have sprung. Much of the morphological evidence which has led to this conclusion is of too technical a character to be set forth here. It must suffice for our purpose to briefly point out a few of the more striking and radical of the many structural modifications, which a study of fossils recovered from Tertiary deposits, reveals to us was taking place in mammalian life throughout the whole of that changeful period. And as the phylogeny of the Equidæ or horse family, as it may be gathered from the geological record, lends itself most readily to this purpose, we will take this to begin with.

There are two particular features about the morphology of the horse which enables us to follow up and trace out fairly closely his evolutionary history. These are the characters of his feet and of his teeth. Both are highly specialized, particularly the former. It was pointed out in an earlier article that the characteristic Amphibians possessed five digits on each of their limbs. They passed this anatomical feature on to the Reptiles; the typical forms of which also possessed five digits. The early generalized mammals were likewise characterized by the same number; and many modern mammals still retain them, notably man and the other Primates. The horse and his collateral relatives—the ass, the zebra, and the quagga—have lost all their ancestral digits except the middle or third one. They are one-toed animals, and not the least interesting part of their family history is the gradual, sequential way in which this loss of the other four digits came about.

There are good sound reasons for believing that the earliest mammals all walked upon the soles of their feet as many of them to this day still do, man being one of these. Today the horse walks upon the tip of what was earlier his third or middle digit, and his single hard, bony hooves are the modified claws or nails of his remote five-toed ancestors. We cannot entertain the slighest doubt on this head, for the present horse can be traced back, stage by stage, to an early Eocene ancestor, which possessed four serviceable toes, and an additional rudimentary one in the form of a side-splint, on his fore-feet and three fully-developed toes and one rudimentary one on his hind-feet. This creature was about the size and build of a fox and is known to science as Eohippus or the Dawn horse. We cannot doubt that he was descended from an earlier five-toed, plantigrade ancestor, though thus far a five-toed horse has not yet been discovered.

Later on, in the same Eocene epoch, we come upon Orohippus, in the foot of which the rudimentary splint-like toe of Eohippus has altogether disappeared. In the next epoch, the Oligocene, Mesohippus comes to light. This creature is about the size of a sheep and possesses but three serviceable toes on each of its feet, though a vestige of the fourth is seen in the form of

a splint on the fore-feet. Later again in the Miocene we come upon Miohippus, in which the vestigial fourth toe has now entirely disappeared. Later still in the Pliocene we find first Protohippus and then Pliohippus, both bigger than the preceding forms. They were about the size of asses. In the earlier of the two we perceive that the two outside toes are beginning to shrink and shorten; and that the middle one is getting stouter and stronger, and doing most of the work of sustaining and carrying the body. In the later one we find that the two side-toes have become mere splints, and that the creature has now become a one-toed animal; but carries still the evidence of its descent from a three-toed ancestor in the form of a pair of side-splints.

With the Quaternary comes Equus, the modern horse; and in the small side-splints which still linger with him, and which occasionally give him trouble in his legs, he bears the marks of his descent from a three-toed ancestor, as they in their turn bear the marks of their descent from earlier four-and five-toed forms.

Paralleling this gradual transformation of a five-digited foot into a single-digited one, is the transformation of the two leg-bones, which have become in the same gradual way consolidated into a single bone. A similar transformation is seen to have taken place in the characters of the teeth, which have become progressively longer and more complex in their structure, and thus better adapted for the comminution or grinding of the siliceous grasses which had now begun to clothe the Tertiary plains and take the place of the earlier herbage.

Supplementing this evidence of the descent of the horse is that of the evolution of the camel and the elephant. We can trace these back through the Tertiary from form to form in much the same way as we can the horse. It does not seem possible to give an open-minded consideration to this evidence and doubt the evolution of the modern horse, the camel and the elephant from some small five-toed Tertiary ancestor. And just as we may follow back, stage by stage, the evolutionary modifications of these three families in particular, so, in a somewhat less perfect degree, perhaps, has science been able to trace out the evolutionary history of most of the other Quaternary mammals. Among these the aquatic forms, and the members of the Primate order, to which man belongs, are the most interesting from our point of view.

The adaptive radiation of the mammals followed lines very similar to those of their predecessors the Reptiles. Both land and sea furnished habitat zones for them and their distribution seems to have been world-wide.

The marine mammals are interesting from many points of view, but in this inquiry chiefly because they illustrate so clearly the principle of "reversive evolution." These warm-blooded, air-breathing sea-animals—the whales, dolphins or porpoises, the seals, walruses, manatees, and sea-otters—all began life, or perhaps it would be more correct to say, their Tertiary ancestors all began their lives as land animals; and then later under the pressure of the struggle for existence, or because they found an aquatic life more agreeable returned to the sea and slowly, stage by stage, became adapted for marine life.

As far as we can gather from the evidence at our disposal the ancestors of the whales were the first to adopt this mode of existence. A fossil form found in late Eocene deposits is known to us by the term Zeuglodon (Greek zeugle, yoke; and odont, tooth). This creature shows a high specialization for a marine habitat. It exhibits a long eel-shaped body, recalling the form of many of the aquatic reptiles and amphibians and the fusiform fish.

In the opinion of Osborn, Zeuglodon originated from a purely terrestrial mammal related to the fossil,

wolf-like Hyænodon of Eocene times, which had itself earlier sprung from an arboreal ancestor. It must thus have passed through three different life-zones and three distinct life-phases. The Archæoceti or ancient cetaceans, formed a very specialized side-branch of the early toothed whales and seem to have died out before the close of the Eocene, when the ancestors of the modern whales first appear. These latter were all toothed animals. Some of them, notably the baleen whales have since, by adaptive modification, lost their teeth and become toothless animals. That the latter once possessed teeth is perfectly clear from the biogenetic fact that their offspring are born with teeth and only lose them as they mature and take on the specialized characters of their immediate, toothless ancestors.

Both whales and seals would appear to have been originally carnivores. The manatees—which include the sea-cows or sea-horses, as they are variously called, and the dugongs —are herbaceous animals, living upon aquatic vegetation. They are descended, it is thought, from the same original stock as the elephant. The walrus has affinities with the seal and probably had a similar origin; possibly from the same stock as the bear. Its chief food is clams, which it digs up with its long, pointed tusks.

The sea-otter is the least specialized of all the marine mammals, and shows most plainly that it is a modified land animal. It is closely related to the river-otter and more distantly to the marten, weasel, skunk, etc. Its ancestors took to a marine existence much later than did those of the other sea-mammals. Its body and limbs are much less modified along fish lines than theirs, but yet show interesting adaptations, of a more or less intermediate type, which fit it for its present mode of life. The hind limbs have become greatly enlarged and are fully webbed, resembling in some respects the flippers of the seal, thereby suggesting the evolutionary stages by which these organs may have reached their present form. They still carry a set of small claws. The fore-feet, on the other hand, have become smaller, but are likewise webbed and claw-tipped. Its body, like that of the hair-seal, still retains its original hairy covering, which makes its pelt so valuable to us.

The interesting point about these sea-mammals is that they one and all exhibit, in a greater or less degree, a remarkable adaptation to their present mode of existence. Some, like the whales and dolphins, have entirely lost their hind-limbs, and their bodies have taken on the general outlines of the fusiform fishes; while their fore-limbs have become highly specialized into flippers or fin-like organs. Others, while still retaining their hind-limbs in modified form, have them tucked away behind them, like the feet of a bird in flying, so that they may offer the least possible resistance to rapid motion in the water. Both flippers and hind-limbs still retain, in some form or other, the original five digits of their remote amphibian ancestors.

Few things bring out more clearly the adaptive power of animals, and nature's ability to fit them for the mode of life they have adopted, than the fundamental homologies, or structural affinities, which underlie their fore-limbs. Flippers, fore-legs, wings, arms; all alike are modifications of an earlier and less specialized organ, whatever that may have been. No morphologist entertains any doubt on this head. Nothing is more certain for him than that they all had a common origin, whatever that may be proved to be, notwithstanding the radical differences they show in form and function today. And just as it has been shown that the wings of a bird are the modified fore-limbs of its reptilian ancestor, so it may be shown that the flippers of the seal and other aquatic mammals are modifications of the fore-limbs of animals that formerly lived and walked on the land.

Just as the sea-mammals illustrate for us the principle of reversive evolution, so the Primates best illustrate the principle of progressive evolution. Let us now see what may be learned of their phylogenic history. No group of mammals can be as interesting to man as that which constitutes the Primate order; for to this man himself is shown, by his structural characters, closely to belong.

The earliest and least specialized of the Primates are the lemurs or pro-simiæ, as they are otherwise called. They first appear in the Early Eocene, and their structural characters resemble so closely those of the generalized insectivors of that period that it is sometimes difficult to distinguish the one from the other. No doubt, therefore, can exist as to their genetic relationship or the direct line of their descent. They probably first became differentiated from the primitive insectivors in late Cretaceous times, for by the beginning of the Tertiary period they had split into two separate branches known as the Lemuroidea and the Tarsioidea. This latter branch is the more important one for us, because from some member of it sprang later the higher Primates—the monkeys, apes and man.

Their habit of living largely in the trees led to an enhancement of their sense of vision, which was accompanied by a corresponding impairment or lessening of their sense of smell, the sense most highly developed in the primitive mammals. This gave rise to profound and far-reaching modifications in the structure of their brains, and started the Primates along that line of evolution which ultimately resulted in man.

The only uncertain thing about their past is their place of origin. Fossil evidence shows them to have been widely distributed early in Tertiary times. We know that both lemurs and monkeys lived on the North American continent during the Eocene; and some high authorities claim the central portions of America as the place of origin of both lemurs and monkeys. Others regard India as the scene of their evolution, since the region of the Siwalik Hills is found especially rich in fossil remains of Tertiary lemurs, monkeys and apes. The Eocene and Oligocene formations of Europe have also yielded remains of primitive lemurs. We know, therefore, that their distribution was practically world-wide.

The lemuroid branch of the Primates has persisted down to our own times; and many different genera and species of them are found today in India and the islands farther eastward, and also in Africa. In this latter region they are especially characteristic of the island of Madagascar, where they form about one-half of the entire mammalian fauna.

Of the Tarsioidea, only one genus exists today, the best known representative of which is the Spectral Tarsier, now found in Borneo, Java and the Philippines. Before the close of the Eocene some member of this branch must have acquired the power of stereoscopic vision. This led to his transformation into a primitive monkey, with a considerable increase in the size of his brain and a marked advance in his powers of skilled movement and in general intelligence.

From this primitive simian arose, by progressive modification, all the later monkeys and, through them, the Apes and Man. Structurally speaking, they show considerable advance upon the earlier and more primitively - organized Lemuroids, some of which to this day show marsupial characters in the form of a rudimentary pouch; and, though as a rule they have but a single pair of pectoral teats for suckling their young, they sometimes show an additional abdominal or even inguinal (groin) pair of these organs.

Their dentition, too, is more primitive, both in the character and in the number of their teeth. They possess an extra pre-molar on each side of their jaws. This gives them a total of 36 teeth instead of the 32 characteristic of all the anthropoidea

or upper division of the Primates, with the exception of the American Cebidae, which also possess these extra pre-molars, as well as many other primitive characteristics.

The more primitive characters of the New World monkeys plainly show us that a division of the monkeys must have taken place early in Eocene times, and that the American branch must have retained in a larger measure the morphological characters of the Lemuroids; for they are much more primitive and closer to them in many ways than are the members of the Old World branch. According to those authorities, who, like Elliot Smith, regard Central America as the seat of the evolution and dispersion of the Anthropoidea, groups of Lemurs, Tarsioids and primitive monkeys must have left this region and wandered by some of the early land bridges which then connected the Old and New Worlds, into Africa, Asia and Europe.

Later in the Tertiary period, when these land bridges no longer existed, the separation between the Old and New World monkeys became complete; and each division evolved along lines of its own which resulted in the many deeply-seated morphological differences we find in the two branches today. This separation and independent evolution would be the same, it may be pointed out, whether India or any other portion of the Old World was the place of their origination. It would merely mean that the migratory bands had gone westward rather than eastward. The differential results would be the same when once the separation had come about.

The question of the centre of the evolution and dispersion of the Anthropoidea, while of considerable interest in itself, is not of primary importance in this inquiry, so we need not involve ourselves in a discussion of it here, beyond saying that it has not been made easier of settlement by the recent discovery of two fossil anthropoid teeth in the Tertiary sediments of Nebraska. The creature to whom these teeth belonged has been named Hespero-pithecus, or the Western Ape. The characters of the teeth are said to show his close relationship to the Hominidæ or human family. He is of late Tertiary times.

This discovery has proved equally disconcerting to both sides, for wherever the place of origin of the early monkeys might be thought to be, it was generally agreed that the Old World was the scene of the evolution of the later man-apes, and that the separation of the two branches of the monkeys took place before their evolution came about. Now if this common view of the Old World origination of the man-apes is to be still maintained, we must conclude that the land connections between the Old and New Worlds were not cut off until after the evolution of the higher apes had taken place; and that some of them must have found their way from the Old to the New World by these routes.

There are no insuperable difficulties in the way of taking this view of the matter. We know that such Old World animals as the great elephants, the sabre-toothed tiger, and others, found their way into America in Tertiary times; as likewise did the camels, now known to have originated in the New World, find their way, on the other hand, into the Old World.

Until, therefore, other material proofs of the presence of the higher apes in the New World of earlier date than Hespero-pithecus may be brought to light, we may still hold the view that they first appeared in the Old World, where most of the fossil remains of their collateral relative, man, are also found.

The first record we have of the Anthropoid, or Man-like Apes, comes from North Africa. In the early Oligocene deposits of the Egyptian Fayum the remains of three fossil Primates have been discovered. One of these was a small tailless ape with primitive Gibbon-like characters, to which the name Propliopithecus has

been given. From it, or some kindred form, the modern Gibbon and Siamang, the smallest of the living anthropoids, are believed to have sprung. Another was a tailed monkey of the Old World Catarrhine type.

We gather from these fossil forms that the Old World or Catarrhine monkeys had undergone important structural changes since their separation from the New World or Platyrrhine branch. Just as some member of the Tarsioids had given rise to a primitive monkey, so from some member of the Catarrhine stock sprang the primitive apes.

Between the period of Propliopithecus and the early part of the Miocene, large numbers of anthropoids must have come into existence; for their fossilized remains are found in various parts of the world in the deposits of this period, in Africa, in Asia and in Europe. In India, in particular, many new forms appear, some of which, it is held, gave rise to the other three members of the Simiidæ, or anthropoid family—the Orang, the Chimpanzee and the Gorilla—as well as to the earliest types of the Hominidæ or human family. Palæontologists are now generally agreed that by the middle of the Miocene epoch the differentiation of the Simiidæ and the Hominidæ had already begun.

Of the former, many characteristic types are known. One of the more interesting of these is Pliopithecus, from Europe, a direct descendant seemingly of the more primitive Oligocene Propliopithecus. Its Gibbon-like characters are so marked that it might well represent the ancestral form of the modern Gibbons. Another is Dryopithecus, from the Miocene deposits of France, looked upon by some authorities as distantly related to the Hominidæ. Still another is Sivapithecus, from India. Dr. Pilgrim, the discoverer of the remains, from which this new genus has been created, has claimed for it relationship with the human family; but this view has not been very generally accepted. Yet Sivapithecus, whether regarded as within or without the Hominidæ, will always be of deep interest for us, inasmuch as it exhibits strong humanoid characters in its teeth, thus pointing directly towards Man. We know, too, that in the Miocene there roamed among the foothills of the Himalayas large numbers of Apes, whose structural characters show them to be closely akin to the modern Orangs, Chimpanzees, Gorillas and Primitive Man. We can scarcely doubt, therefore, that some of these Indian forms stand in the direct line of descent of the modern anthropoids and man.

In the face of this evidence, it is difficult to avoid the conclusion that this region was the main centre of their evolution and distribution. Here most probably arose, not later than the middle of the Miocene, that fateful creature from whose loins were to spring the present-day anthropoid Apes, on the one hand, and Mankind on the other.

CHAPTER XX.

Embryological Evidence of Man's Lowly Descent

WE BROUGHT the last chapter to a close with a sketch of the phylogenic history of the Primates, the highest order of the mammals, and saw that the fossil and morphological evidence at our disposal led to the conclusion that the higher and later members of this order arose about the middle of the Miocene epoch, probably among the foothills of the Himalayas; and that among them there must have existed some form that could be regarded as the common ancestor of the present-day anthropoids and man.

When we consider man on his physical side there is no escape from the conclusion that he belongs to the animal kingdom, is a mammal, a member of the Primate order, and closely related to the higher apes, sharing, indeed, a common descent with them from the same ancestor.

We are driven to accept this view of his origin, no matter how repugnant the idea may be to our self-esteem, or how much it may conflict with earlier theological teachings, unless we are prepared to deny the validity of modern zoological research and the obvious facts of comparative anatomy.

To the open-minded person who is desirous of reaching the truth above all things, and is willing to lay aside his preconceptions concerning the origin of man and follow the findings of his reason, the factual proofs of man's genetic relationship to the other members of the Primate order are of so conclusive and convincing a nature as to leave him no alternative but to accept them, if he is to avoid stultifying his own intelligence.

It is admitted on all sides today that no fundamental, anatomical differences can be shown to exist between man and the anthropoids; and that when the latter and the more primitive monkeys and lemurs are compared one with another they present vastly greater structural differences, both internal and external, than are found between the higher apes and man. Dr. Sir Arthur Keith, Conservator of the College of Surgeons in London, and one of the outstanding comparative anatomists of our day, has given particular study to the physical characters of man and the apes, and he informs us that many of these characters are not only peculiar to these two groups themselves and found in no other mammals, but are of such a fundamental nature as to make it impossible to doubt the close relationship between the two, or the fact that they represent today two divergent lines of evolution sprung from a common ancestor.

Man, he tells us, shares as many as 396 common anatomical characters with the Chimpanzee, 385 with the Gorilla, 272 with the Orang and 188 with the Gibbon.

These are very significant facts, and when taken in conjunction with a number of others of equal cogency, drawn from embryology, palæontology, blood tests and vestigial organs, their cumulative force becomes so strong as to sweep aside all possible objection that might be urged against them and leave those who would oppose them without any substantial argument with which to meet them. There is, indeed, no reasonable explanation left to account for them if we reject a direct relationship and a common descent for man and the anthropoids. Let us here briefly consider some of these facts; we shall find them very convincing. First, those from embryology.

We saw in an earlier chapter that

every living form began its existence in the same way, namely, as a tiny cell or life-germ. We saw, too, that some organisms never got beyond this early stage, but became more or less stereotyped and fixed. These are the Protozoans or single-celled forms. Others by association and integration became the compound, complex Metazoans or higher life-forms. The truth of this statement is beyond question. It is the most fundamental fact in the life-realm, and one upon which all our biological authorities are absolutely agreed. Man forms no exception to this general rule of life. He begins his corporeal existence in identically the same way as the apes, and both they and he in the same way as the other creatures.

The human germ-cell differs in no essential respect, as far as the nature of its physical elements is concerned, from that of the ape or any other animal. Its earliest stages of development are the same as theirs; its potentialities only are different. Indeed, considerable time must elapse after the zygote, or impregnated ovum, has begun its individual growth, before it is possible to distinguish between the embryo of a dog, an ape and a man. And what is more significant in the case of the human embryo, the earliest characters that manifest themselves in the first weeks of its uterine life, suggest any other form rather than a human one. It is not till the eighth week of its existence that the earliest Primate characters first appear; and not till after the sixth month that all the distinctively human characters manifest themselves.

Our embryologists of today are familiar with every stage of development the human embryo passes through. There is no guesswork about our knowledge in this regard. Let us, therefore, make ourselves acquainted with some of the least technical parts of it.

At the period of impregnation the human ovum is a tiny speck of organic matter too small for the unaided human eye to detect, since it ranges only from about 1-120th to 1-140th of an inch in diameter. Like the embryo of other mammals, it grows very slowly in the earlier stages of its development, being at the end of the first month only about an inch in length. At the end of two months it has more than doubled its length, being then about two and a half inches. At three months it is about five inches; at the fifth month about six or seven inches; at the seventh nearly a foot long; at eight months about fourteen inches, and at nine months, or the period of birth, normally from eighteen to twenty inches. In this gradual mode of development there is no essential difference between the growth of the human embryo and that of any other of the mammals.

After the seventh day of development the human ovum becomes visible to the naked eye. By the twelfth day it is a vesicle-like body about the size of a small pea. On the 13th or 14th day the embryo is about the size of a horse-fly and resembles one of the early worm-like organisms doubled up. If straightened out it is seen to be about half an inch in length. Between the second and third week it passes through several of the earlier life-stages, represented today by the colonizing protozoans and the lower metazoans. In the fourth week, or about the 25th day, it is seen to reach a definite fish stage. At this time and stage of its development there is very little difference between the mammal embryo and the lowliest of the fish-forms. By this time the gastrula stage has well begun. This is the two-layered stage we saw was characteristic of the lower metazoan forms, such as Hydra, gastrulation being the process by which the "morula," or mulberry-shaped aggregation of single cells, is converted into a two-layered organism with an internal cavity or enteron. The "invagination" or indenting of the morula, which is to give rise to the future stomach and mouth, is very

clearly seen. The primitive streak and groove earlier manifested is now turning into the three layers of the ectoderm, the mesoderm and the endoderm, from which later are developed all the organs and specialized parts of the higher creatures. As in the early and lowly organisms, the human embryo at this stage has but one orifice, the oral one. In its skeletal outlines it has, by this time, left well behind the invertebrate forms. It is seen to be passing through the structural phases characteristic of the amphioxus or lancelet, which we earlier saw represented the lowest of the vertebrate forms. What is later to become the backbone of the embryo is now seen as a notochord, such as the most primitive fishes possess. The heart, too, of the embryo at this stage is only a one-chambered organ, the same as that in the lancelet; and the prebrain is similar to that in the lamprey, where the olfactory lobes form the larger portion and are the most highly developed, as in the lower mammalian forms. It is during this fish-stage in the life of the embryo that the gill-slits and gill-arches manifest themselves. By the fifth week these fish-like phases begin to pass away and the characters of the land animals make their first appearance in the form of the limb-buds, which later develop into the fully-formed limbs.

During these first five weeks in the embryonic life of the mammals, the life-germ passes through eight distinct phases, every one of which is represented today by some lowly-organized living form which has become fixed and settled in its habits and organization.

During the sixth week the gill-slits close up, the digits of the limbs begin to make their appearance, and the tail, which has outgrown the budding limbs in length, reaches its maximum development. It is at this stage actually longer than the hind limbs themselves. The segmentation or jointing of the limbs also now takes place. At this stage the digits are webbed like those of the frog. This, like the excessive olfactory lobes, when there is no need of a sense of smell, is a very significant feature and has absolutely no functional meaning or any reasonable explanation apart from the doctrine of organic evolution and the biogenetic law of recapitulation.

In the seventh week the embryo becomes what is technically called a fœtus. By this time the digits are clearly demarcated and the tail begins to shrink and gradually disappear. Retrogression of this useless organ has set in. In this connection it is of interest to point out that instances are well known where the human infant has been born with a short tail. Such a feature is readily explained from the evolutionary point of view by regarding it as an instance of atavism, where some remote ancestral phase has persisted throughout the whole embryological and fœtal life down to the birth period. Atavisms of this kind are not at all infrequent, but they are distinctly puzzling and without rational explanation if man is regarded as having no genetic relationship with other and lower life-forms.

About this time the heart undergoes modification and passes from a one-chambered organ to a right-and-left two-chambered one. In the eighth week the fœtus begins to exhibit its earliest Primate characters From this time onwards it develops along Primate lines, gradually leaving the lemuroid and monkey stages and passing into those of the anthropoid, which are closely parallel to those of man till near the birth period. Another significant point to be observed is that in all vertebrate animals below the anthropoids the spinal column forms a horizontal axis. In the anthropoids and man it forms a vertical one. Keith has no doubt that the orthograde or upright posture was evolved from the earlier pronograde or inclined posture; and the close relationship of the anthropoids to the lower prono-

grade Primates assuredly warrants this conclusion.

The evolutionary principle is also well exemplified in the growth of the brain. The Primate brain shows great advance upon the brains of the other mammals, and has moreover characters peculiar to itself; and we can watch the development of these, step by step, from the lower Primates right through to man. Between the higher apes and man the brain differences are vastly less than those between the anthropoids and the more primitive monkeys. Keith, Smith Woodward, Elliot Smith, and other high authorities in these matters, tell us that no one can study the brain of man without being convinced that it has passed through those stages represented by the brain of the anthropoids. The differences between them are seen to be those of degree only, and not of kind.

They affirm that the evolution of the human skull during the pre-natal period exhibits all the phases through which those of the earlier and more primitive life-forms pass. The lines of development of the skull, for example, have always been closely related to the functions of respiration. When the pulmonary (lung) method replaces the earlier branchial (gill) system, which we saw had a temporary existence in the fourth week of the development of the human embryo, the nasal air-passages become separated from the mouth by a primitive palate, such as is characteristic of amphibians, reptiles and birds. We can watch the development of this palate stage by stage in the human embryo. Again in the second month the skull of the human embryo is purely cartilaginous in its nature. This is the characteristic condition of the skulls of all that group of lower vertebrates represented today by such fishes as the dog-fish, the rays and the sharks. The divisions of the skull of the latter are exactly paralleled in the fœtal skull of man in the eighth week of its development.

One is tempted to ask here: Why does the human embryo assume or pass through all these non-human phases? Why this recapitulation of features characteristic of more lowly forms than the human, if there be no evolutionary process and no biogenetic law?

Truly it may be said of man that, like the frog and other amphibians, in his embryological life he literally climbs up his own ancestral tree.

During the latter phases of their uterine existence the embryos of man and the anthropoids resemble each other so closely that it takes a trained observer to distinguish between them. Sir Arthur Keith has stated in one of his recent lectures that, in the museum of the College of Surgeons, there is on exhibition the pregnant uterus of a Chimpanzee, which is dissected in such a manner as to expose a fœtus in the seventh month of development. He points out how closely the fœtus resembles that of a woman, and that it could easily be mistaken for a human fœtus by any but an instructed observer. The skin of the young body is nude, save for the presence of the same fine lanugo or downy hair seen on the body of the human fœtus in the same stage of development, and which usually disappears before the birth period. Like the tail and webbed digits, this feature occasionally persists through to the time of birth and the child is born with a hairy body, as is normally the case with the young of the anthropoids. The skin of this young chimpanzee shows scarcely any sign of pigmentation resembling in this respect the fœtus of the black races, whose young up to the time of birth do not possess the dark skin of their parents. In appearance it is of an ashen-grey color, and the scalp is covered with brown hair, which is distributed over the head in a distinctly human manner, quite unlike that of the mature chimpanzee, whose hair, moreover, is never of that color.

Keith, from his studies of this chimpanzee fœtus, has drawn the momentous conclusion—in which he

FIG. I.

COMPARISON of the embryos of the Pig, Rabbit, Monkey, and Man at corresponding stages of development. The embryos of each animal are arranged in the vertical columns according to age, beginning with the youngest stage at the top. Stage A of the human embryo is fully labelled and the corresponding structures in the other embryos can be noted. a, head region; b, eye; c, ear; d, gill slits; e, heart; f, fore limb; g, primitive muscle segments; h, hind limb; i, tail region. Slightly modified from K. Guenther, after Keibel.

is supported by Professor Bolk of Amsterdam, who possesses a similar fœtus, and who drew from its study a similar but independent conclusion to that of Keith—that man came by his naked skin and the blond race by its absence of pigmentation by inheriting a fœtal condition from some anthropoid ancestor. What was clearly a passing phase in the fœtal life of the anthropoids, as exhibited by these modern chimpanzees, had at some time in the distant past persisted through to the birth period, and the first blondish and hairless ape was brought into being. From this creature, by the fixation and inheritance of these humanoid characters, man arose. It may be added that Keith holds the view that the pigmented races—the black, yellow and red races—are later in time than, and modified forms of, the more primitive blond type. This type is certainly more hairy than any of the others, and in that respect, at least, is closer to the apes.

Whether we accept this weighty deduction of Keith and Bolk, or not, it must be admitted that it is an extremely plausible one and does no violence to the facts from which it is drawn; and also that the characters displayed by man must have arisen in the first place, if organic evolution is the fundamental principle we believe it to be, in some such way as is here suggested. We know that new forms may suddenly arise in this manner. It is quite possible that man's first appearance was due to a "mutation" or "sudden leap" of the de Vries kind. Our recently-acquired knowledge of the important part which the "hormones" or "chemical messengers" sent out by the ductless glands into the blood stream, play in the upbuilding and molding of our bodies and characters, especially in the uterine period of our existence, fully warrants our drawing such a conclusion and holding such a view.

Keith regards the long, developmental, pre-natal period of the higher animals as an extremely favorable time for the activities of the ductless or endocrine glands; and thinks that it gives the hormone system the necessary shelter and opportunity for working out its effects and for elaborating new experiments.

It is under this system, he believes, that all new characters arise and are developed during the early life of the fœtus. The uterine period he regards as the time of elaboration and experiment on the part of the growth mechanism. All kinds of growths and characters are apt to arise at this time, he points out, but under the influence of heredity these are usually reabsorbed and entirely disappear before birth. At times, however, some of these new characters thus elaborated and brought into existence by the activity of the hormone system, persist, become fixed, and, therefore, hereditary; and thus new forms and types arise. He believes that the "hormone system"—that is, the secretions of the ductless glands, which are poured directly into the blood-stream — is the agency by which both the racial differentiations of mankind and the distinctive characters, which mark off the human division of the Primates from the anthropoid one, were brought about.

It must be conceded whether we accept these conclusions of Keith or not, that the embryological and fœtal evidence we have just considered points strongly to the descent of man from lower forms of life and to a genetic relationship with the other Primates, and especially to the anthropoid apes.

In the next chapter we will devote our attention to the evidences of man's presence on the earth in past times, and see what we may learn from them of his antiquity and of his earlier physical characters and affiliations, as these are revealed to us by the palæontological record.

CHAPTER XXI.

The Anthropoids and Man

PERHAPS in no other age has human knowledge advanced so rapidly as in our own, and in no subject is this more apparent than in our conceptions of the past history of our earth and the antiquity of the human race. Less than a hundred years ago it was commonly held and taught not only by religious teachers but also quite generally by men of scientific attainments, that the world and man upon it had come into existence only about 6000 years ago.

Archbishop Usher, in the 17th century, by calculating the ages of the biblical patriarchs, and the historical events of the Jewish people, estimated that the Creation of the world and man had taken place about 4000 years before the birth of Christ. In the same century, Dr. John Lightfoot, vice-chancellor of Cambridge University and one of the most erudite scholars of his time, quite solemnly made a similar calculation and arrived at the conclusion that the Creation had taken place at the hour of 9 o'clock in the morning on the 23rd day of October exactly 4004 years before the Christian era began. These views were quite commonly accepted down to the middle of the last century, many people, indeed, of uncritical mind holding them to this day, and man's past was thought to be limited to this brief period. Darwin himself, we know from his own statements, was a firm believer in special Creation up to the year 1843, when he went upon his voyage as naturalist in the Beagle, and was accustomed to take the first chapters of Genesis quite literally and without question.

It seems almost impossible in the light of our present-day knowledge, to believe that mankind could have remained so long in ignorance of its past records and its remote origin. But pre-history was then a study quite unknown, and the term "prehistoric," now so indispensable, had not even been coined. Indeed, it was not till the year 1858, which saw the first public notification of the views independently arrived at by Darwin and Wallace on the origin of species, that the antiquity of man and his presence here on this earth many thousands of years before the date assigned for the Creation by Usher and Lightfoot, was accepted as a demonstrable fact by science itself.

It is a remarkable and rather significant incident, we have always thought, that at the very meeting of the Royal Society, at which Darwin's and Wallace's papers relating to the origin of species were read, Dr. Prestwich, the then highest living authority on Tertiary formations, presented a paper on the antiquity of man, in which he brought forward a large body of material evidence which made it quite clear that man had been a contemporary of the early Pleistocene mammals. The evidence he offered in support of this fact was of such a convincing and indisputable character, that it was at once accepted by the Society, and man's antiquity was regarded as established from that day forward.

Since that date, now sixty-six years ago, evidence of man's presence here in distant times has come in from all sides, until today there is no doubt at all in the minds of our anthropological authorities that man's past on the earth extends far into the

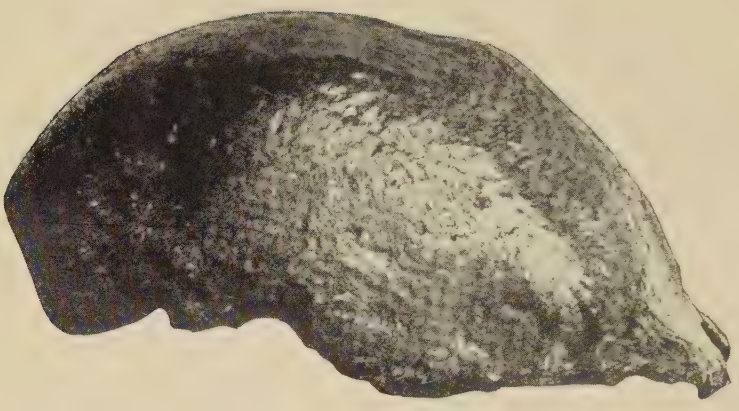

FIG. II.

Skull of the Javan Ape-man, Pithecanthropus erectus.
(After Dubois.)

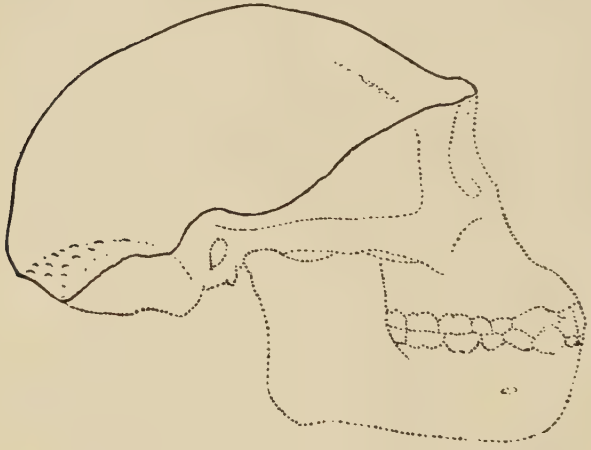

FIG. III.

Theoretical reconstruction of the entire skull of the Javan Ape-man.
(After Dubois.)

Tertiary period; most probably, as we saw in Chapter XIX., to the middle of the Miocene epoch. This gives man an antiquity of from two to three millions of years.

The evidence upon which this remote age of man is established is of the most undeniable kind. It is both material and direct and consists of his own skeletal remains on the one hand and of his stone artifacts, that is his manufactured tools and implements, on the other.

Throughout the whole of the Pleistocene epoch of the Quaternary both are found in such circumstances and under such conditions as to make it impossible to doubt their age. Both are associated with the fossilized remains of animals long since extinct, but known to have certainly lived at the close of the Pliocene and the beginning of the Pleistocene.

When we pass beyond the Quaternary and get into the Tertiary, we still find abundant evidence of man's presence during the late phases of this period in his skilfully-made stone tools and in his hearth-sites. These latter teach us that he had discovered fire thus early and knew how to use it. In the Pliocene his osseous remains are not so much in evidence as in the Pleistocene.

This is easily understood. The perishable nature of such material readily accounts for its scantiness on the one hand, and on the other its existence is only brought to light as a rule by some lucky accident, which cannot be expected to happen often. We can scarcely hope, therefore, ever to secure much evidence of a skeletal nature belonging to those remote times.

The scantiness of his fossilized bones does not, however, materially affect the question of his antiquity. His presence here throughout the larger portion of the latter half of the Tertiary is just as plainly evidenced by his imperishable artifacts in stone as it would be by his skeletal remains themselves, desirable as it is to recover and possess these. No other creature save man is a deliberate tool-maker; and when we find stone objects bearing unmistakable signs of intelligent and purposive fashioning in any undisturbed geological deposit, the stratigraphical characters of which offer indisputable evidence of its age, we may feel quite sure that the creature who fashioned these objects lived either at or before the time when this deposit was being formed.

There is a very general concurrence of opinion among our archæological authorities today that man may be traced back by means of his artifacts well into the Miocene. As might be expected, we find these artifacts showing less and less skill in their fashioning, becoming cruder and cruder in form, the farther back we go; until we reach a stage when it is no longer easy to distinguish between the chance products of nature and those of human effort.

If man has sprung from some lower Primate and his intelligence has gradually evolved, as we believe it has, this is exactly what we ought to find; and the very fact that this is what we do find, is in itself no slight evidence of his evolutionary ascent from lower and less intelligent forms.

Our early studies of the handiwork of primitive man led us to divide his prehistoric past into two great divisions. These are known as the Neolithic or New-stone age, and the Palæolithic or Old-stone age. The former dates back from the present about ten or twelve thousand years, and merges into the age of metals. The latter extends from the dawn of the Neolithic to about the close of the Pliocene or the beginning of the Pleistocene. It covers by far, therefore the longest portion of man's past."

The distinction between the two ages is an arbitrary one and lies in the method by which he fashioned his stone implements. Down to Neolithic times, in Western Europe where our studies of Palæolithic man first began, this was accomplished mainly by chipping or flaking, never apparently by grinding or rubbing. The charac-

teristic Neolithic implement on the contrary is marked by its smoothed and polished appearance, the process of chipping having given way by this time largely, though by no means exclusively, to grinding or rubbing.

The long Palæolithic age of man has been subdivided into a series of successive cultural periods. The whole Pleistocene epoch is taken up with some twelve of these. They are distinguished one from another mainly by the style, shape and workmanship of the artifacts which characterize them. Beyond the Pleistocene and extending through the Pliocene into the Upper Miocene is another long and somewhat ill-defined period, known broadly as the Eolithic or Dawn-stone age, because the stone implements recovered from the geological deposits of this age become relatively cruder and exhibit less and less skill as the recession of time goes on, until we reach a point, as was remarked just now, when it is difficult to decide whether we are dealing with the work of man's hands or the chance products of nature.

According to some high authorities on these matters some of these "Eoliths," as they are called, date back to the Upper Miocene and show even at that remote period distinct evidence of human workmanship. Certainly in the case of some, at least, of them it is difficult to distinguish between them and the flaked implements we know were made and used by primitive peoples of more recent times; or even those manufactured by our own American Indians, only a few generations ago.

But whatever doubt may be attached to the Miocene Eoliths in respect of the agency by which they were fashioned, whether by nature or by man, there can be little or none with respect to those of the Pliocene. Mr. J. Reid Moir's recent extended researches in East Anglia in England have removed all doubt about the existence of man as a tool-maker in this region in Pliocene times. The geological formation known as the Coralline Crag has yielded too many flaked flints, bearing unmistakable evidence of human workmanship, for us to doubt that man was alive and able to fashion tools of stone in this epoch, to which it is generally agreed the Coralline Crag belongs.

And now having acquainted ourselves with the nature of the evidence upon which the antiquity of man and his presence here as an intelligent creature and tool-maker in the Tertiary has been established, let us see what we may learn of his physical characters and appearance in those remote times, insofar as these may be gathered from his fossilized remains; and also whether they offer any evidence of his relationship to the anthropoid apes.

If man and the anthropoids have a common origin and represent today two divergent lines of evolution, as science teaches, then it is quite obvious that the farther back we go in their phylogenic history, the closer they should come together and the more alike in their physical characters should they appear. There seems to be no escape from this conclusion.

But when we say that man and the anthropoids should become more alike in their physical characters the farther back in their phylogeny we go, what exactly do we mean? Do we mean that man will become more like the apes as we know them today, or that the apes will become more like man? Or do we mean neither of these two things, but rather that both man and the apes will approximate more and more closely to a type which, while it necessarily has certain characters in common with both, will be found to be unlike either of them as they are today?

A little reflection will show us that this last is what we really should mean, whatever preconceptions we may have entertained to the contrary. The knowledge we have gained of the evolutionary process should suggest to us that the distinctions which divide man and the anthro-

FIG. IV.

FIG. V.

Photograph of front (Fig. 4) and left side (Fig. 5) of skull of Rhodesian man, showing large face with prominent brow-ridges; less than one-half natural size. Neanderthal type.

Note gorilla-like contour.

(After Smith Woodward.)

poids at the present time are the result of specialization along diverging lines, and that it is highly improbable that this specialization has been all on one side; and, therefore, that neither of them represents today the ancestral type from which both have been derived.

As a matter of fact we know that each has undergone considerable differentiation, but that of the two the apes are more highly-specialized than man; and in no feature is this more clearly seen than in their general cranial characters. In these respects the apes, and especially the gorilla, which in many other ways most closely resembles man, are, contrary to the view which has been commonly entertained, farther removed from the ancestral type than is man. Except in his greater cranial capacity, that is in the enlargement of his skull and in the evolution of his brain and in other minor features, man has retained the cranial characters of his remote ancestor much more closely than have the anthropoids generally, and the gorilla in particular. But it is only of late years that this has come to be recognized.

When Darwin, Huxley and the other investigators were tracing out the relationships of man and the apes, their knowledge of the latter was largely confined to a few fossil remains and to the several mature living forms; and as a result some of the deductions drawn by them led to the dissemination of views which are no longer tenable in the light of our present-day knowledge.

Till recent years little or nothing was known of the fœtal phases of anthropoid life, or of the distinctive characters exhibited by the young of the apes; and more especially the deep significance of these characters in the light of the biogenetic law, to which reference has been repeatedly made in these articles and whose importance in inquiries of this kind cannot be over estimated.

The lack of this knowledge led to the placing of an undue emphasis upon the simian aspects of fossil man and too little upon the humanoid, especially in respect of his cranial characters. It was too hastily, though very naturally, assumed that the more ancient such fossils were the closer they would approach to the ape type and the farther they would be removed from the human type.

It is not surprising, therefore, that when Dubois in 1891-2 discovered in Java, in sediments believed to be either late Pliocene or early Pleistocene, the partial remains of a Primate which seemed to answer this description, it was very generally regarded as the type of being primitive man ought to be. For while it exhibited humanoid characters of a transitional type it favored the ape more closely than it did man. So much, indeed, was this the case that it was looked upon by some as a gigantic gibbon rather than as a type of primitive man. By others, however, it was hailed as the long-anticipated "missing-link." Dubois named it Pithecanthropus erectus, which means the upright ape-man.

But whether we class this creature with the primitive apes or with primitive man there can be no doubt about its mixed characters. The flat brutish skull, with its prominent over-hanging eye-brow ridges, strongly suggests the modern chimpanzee or gorilla; but against this its cranial capacity or brain volume is far in excess of that of any known ape. This has been found to be a little under 900 cubic centimeters. The significance of this measurement will be realized when it is stated that the maximum capacity of the largest of the man-apes is only a little in excess of 600 c c, while the average of all the great apes runs only about 500 c. c. The range in the brain volume of man, on the other hand, is between 950 c. c. and 1900 c. c.; the standard capacity lying between 1350 c. c. and 1450 c. c.

If we take the average brain volumes of both man and the higher

apes and compare them with that of the Javan ape-man we perceive that the latter lies fairly midway between the other two, thus plainly showing its intermediate, relational character. The same mixed characters are seen in the teeth. They are found to partake about equally of the diagnostic features of both human and anthropoid teeth.

From an examination of its thigh-bone we gather further that it belonged to a creature that walked erect and stood about five feet six inches high; and while this posture is suggestive of the gibbon, we have no knowledge of a gibbon of this height.

What kind of a creature, then, was Pithecanthropus? Was he man or ape? And if the former, does he stand in the direct line of man's ancestry? Does he represent one of the evolutionary phases through which man has passed?

From the time of his discovery down to 1912 it was commonly thought that he did. This view was further confirmed when a little later in 1907 an immense human jaw was discovered lying at the base of an undisturbed stratified deposit of clay and sand 80 feet in thickness, at a place called Mauer near Heidelberg in Germany. This deposit belongs either to late Pliocene or very early Pleistocene times. About this no doubt at all exists, nor about the genuineness of the find. We are, therefore, dealing with a fossil of approximately the same age as the Javan ape-man. The two might indeed, have been contemporaries for aught we know to the contrary, though it is generally thought the Javan type was the older.

The dentition of this mandible removes all doubt about its belonging to a member of the human family. The diagnostic characters of the teeth make this quite certain. At the same time other features of it show strong simian affinities, the most conspicuous of which is its ape-like, underhung chin. The absence of a chin in the human sense of the word is a marked feature in the mandibles of apes and monkeys and early man, and is one of the many features which point to their kinship. As far, then, as we may judge from this jaw, Heidelberg man seems to display the same transitional characters as those seen in Pithecanthropus; but as the teeth are more distinctly human in type than are those of the latter, he has been generally considered as representing a later phase in man's evolution.

Another and subsequent phase was thought to be seen in the type now generally known as "Neanderthal man". Our first knowledge of this remarkably pithecoid race of men actually antedates that of the other two. It came from the discovery of two unique skulls both of which showed strikingly ape-like characters. The first was found at Gibraltar in 1848 and is now known as the "Gibraltar skull". The second was unearthed in a cave with some other bones in the Neanderthal in Germany in 1856, and from this circumstance later gave the name "Neanderthal" to the type. But as the earliest traces of Neanderthal man came to light in the days before the antiquity of man had been established, or his relation to the apes hardly as much as suspected, the pithecoid characters seen in these skulls were generally thought to be due to disease or degeneration, and they aroused little interest outside a limited circle of scientific men. Huxley was one of these, and when shown a cast of the Neanderthal skull remarked that it was the most ape-like he had ever beheld. When compared with the skull of Pithecanthropus it is seen to have the same low crown and retreating forehead, and also the same protruding eye-brow ridges, but its cranial capacity is much greater and shows it to be distinctly within the human class, as does also that of the Gibraltar skull which exhibits much the same simian features.

The discovery of Pithecanthropus

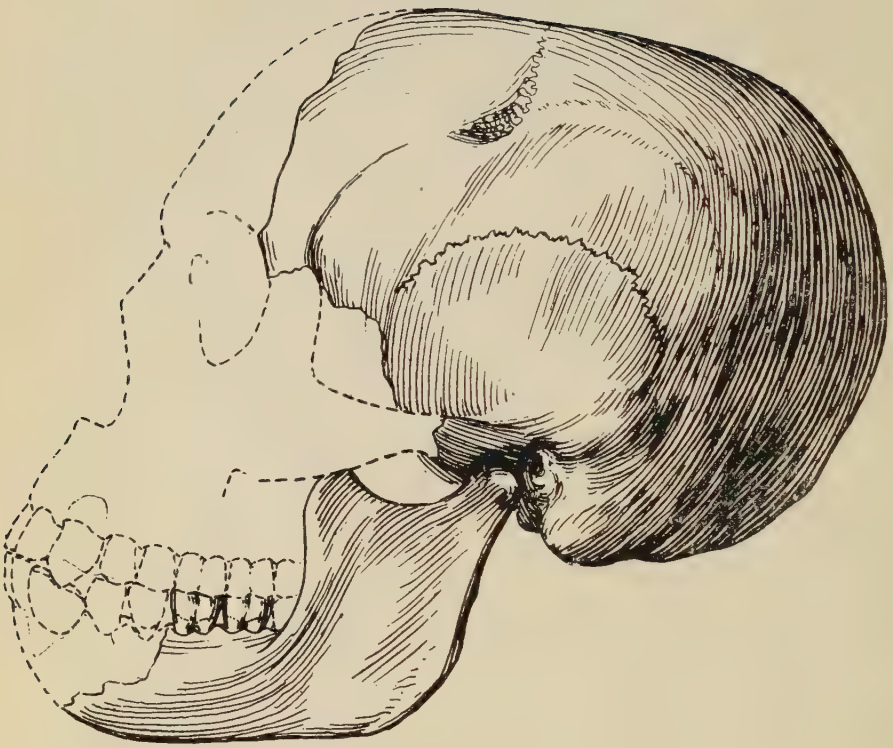

FIG. VI.

EOANTHROPUS DAWSONI.

Re-construction of the Piltdown Skull according to Smith Woodward.

(With acknowledgments.)

FIG. VII.

Top row— 3 normal skulls

Bottom row—young chimpanzee skull, young gorilla skull and young orang-utan skull. Note how like in general contours both types are, difference mainly in size.

FIG. VIII.

Baby orang-utan. (From life)

Observe the human-like contours of the head.

and Heidelberg man recalled these two skulls to memory, and when, later, in 1907 and the four succeeding years, a number of other specimens of this type of skull came to light in different parts of Western Europe, it was no longer possible to resist the conclusion that a race of men of the type of the Neanderthal man had formerly existed in that region.

A third type of primitive man was thus established, and it also was regarded as standing in the direct line of modern man's ancestry though much closer to him than the other two. The age of Neanderthal man falls within the culture period known as the Mousterian, and dates back only about 40 or 50 thousand years. A long interval is thus seen to divide Neanderthal man from Heidelberg man and Pithecanthropus. What of the Palæolithic men of this period? Do we know of any, and if so, what were they like?

Prior to 1912 it was generally thought there was no evidence of their existence. As a matter of fact we were then actually in possession of the remains of a pre-Mousterian race, though they were not recognized as such or regarded as antedating Neanderthal man; because in their general, and especially in their cranial characters they showed a great advance over him and resembled so much more closely the modern type of man than he did. Indeed save for the conspicuous thickness of their crania they differ little in appearance from the men of today.

Looking, then, upon Pithecanthropus, the Heidelberg and Neanderthal men, as anthropologists everywhere did, as witnessing to the successive evolutionary phases through which Palæolithic man had necessarily to pass before the stage of Homo sapiens could be reached, it did not seem possible to regard this modern-looking type of man as preceding the more primitive ape-like Neanderthalers, notwithstanding that all the geological evidence relative to their discovery pointed strongly to their priority, and testified to their greater antiquity; and consequently it was commonly thought that such a type must be later in time than they.

This pre-Mousterian race is known today as the High-terrace men, because their remains have been taken mainly from the upper or 100-foot terraces of the rivers of Western Europe. These ancient river-beds antedate by many thousands of years the lower 50-foot terraces belonging to the time of Mousterian or Neanderthal man. The valleys of the Thames, Somme, Seine and Arno have all revealed specimens of this race. It is best exemplified in the Galley Hill, the Clichy and Olmo types, now well known from Keith's critical description of them.

It was the announcement in 1912 by Dawson and Smith Woodward of the discovery at Piltdown in Sussex, a little time before, of a new type of Palæolithic man, that led to the recognition of the antiquity of the High-terrace men, and the placing of them in their proper sequence in the chronological order.

The distinctive characters displayed by Piltdown man induced Smith Woodward to look upon him as a new genus and to set him in a class by himself; and he is now known to science as Eoanthropus or the Dawn-man. We shall see presently that no more appropriate name could have been given him; for he undoubtedly represents more truly than any other of the Palæolithic types known to us up to the present, the kind of man our earliest human ancestor must have been.

The period in which he seemed to have lived would make him a possible contemporary of Pithecanthropus or Heidelberg man. Like them he would appear to belong to the close of the Pliocene or the beginning of the Pleistocene; and like them he is intermediate in type; but while more distinctly human than they in some of his characters, he is also more markedly simian in others.

Thus while his cranium lacks the

ape-like appearance of the skull of the Javan fossil, as may be seem from the accompanying plate, or of those of the later Neanderthal type, and approximates in its general contours, and in its smooth and well-formed brow, as well as in its brain volume, to the more modern type of head, its mandible is markedly simian, not only in its lack of chin but also in the very pronounced development of its canine or eye-teeth, a feature absent in the Mauer jaw. These are seen to be about the same size as, and have a suggestive resemblance to, the milk or first teeth of the present-day apes. Indeed so disharmonious do the skull and jaw seem to be that at first some doubt arose as to whether the two were really related to each other or not. A more critical examination, however, of both, and the discovery of other diagnostic human remains in the same locality, removed this doubt, and today the two are generally recognized as belonging to one and the same individual.

It can easily be seen that the discovery of Eoanthropus was a very important and at the same time a very disturbing addition to our knowledge of Palæolithic man. If he represented the earliest type of primitive man, and there can be little or no doubt on this point; and if the modern-looking High-terrace men preceded the ape-like Neanderthalers, as the geological evidence shows that they did; what part, then, had these latter, and the earlier Heidelberg men and Pithecanthropus played in the physical evolution of man? If Eoanthropus with his more modern type of skull represents man's earlier human ancestors as we now know he does, where do they come in and what position do they occupy in our genealogical tree?

The presence, so relatively late as the Mousterian period, of so low a type of man as the Neanderthal complicates matters greatly. Preceded by thousands of years by a much higher type of man than themselves, and, as we now know, immediately succeeded by a type as modern and highly-developed as our own, they cannot possibly be regarded any longer as standing in the direct line of our ancestry, nor as representing one of the physical phases through which all mankind had to pass, as was earlier thought to be the case. How, then, are they and also Heidelberg man and Pithecanthropus now to be regarded? In what relation do they stand to ourselves?

There seems to be only one answer to these questions: They must now be looked upon as divergent offshoots from the main human stem, and not as related to us directly at all. In other words: When man was in the making, so to speak, more than one type of him came into existence. We have made acquaintance with five of these, and the more recently discovered Rhodesian man from South Africa would seem to constitute a sixth. (See accompanying plates).

There is nothing strange or incredible about such an idea, though it may be a little novel to some. We know that man's collateral relatives the apes have diverged in just this manner. In the late Miocene and Early Pliocene there were many different genera of these alive on the earth; and today there are at least four distinct genera in existence with several different species among them. If the apes, which are so closely related to man, could thus diverge, why not also man himself? We can entertain no doubt on this point, or that this is the true explanation of these diverse types of men the fossil record reveals to us.

Accepting, then, this view of ancient man, from which of the six known types may modern man be thought to have descended? Or should we look upon any of them as standing in the direct line of his ancestry? Our present knowledge does not enable us to speak with any certainty on this point. Regarding them from the physical point of view or from their resemblance to ourselves, the High-terrace men unquestionably

FIG. IX.

(A.) Characteristic mature gorilla skull, showing bony projections for muscle attachment.

(B.) Immature young gorilla skull, showing ancestral type.

(C.) Typtical human skull, showing same primitive characters seen in the young gorilla.

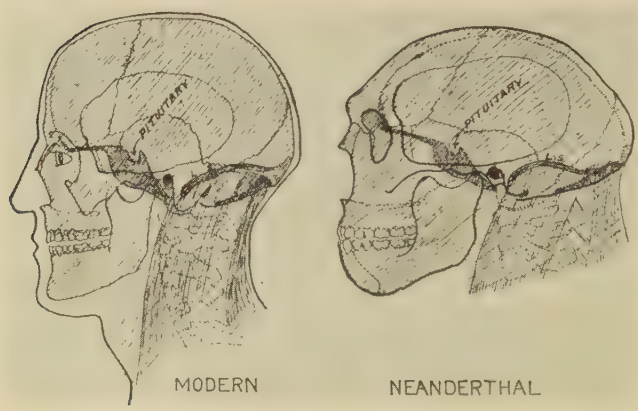

FIG. X.

Diagram showing poise of the head in the modern and Neanderthal types of man.

(After Keith.)

stand nearest to us; and they might very well be our direct Palæolithic ancestors, as they themselves might be the descendants of Eoanthropus. But their connection with the races which appear on the scenes later are as yet very vague, and they may have passed away, as the others seem to have done, without leaving any direct offspring behind them.

The earliest of the known Palæolithic types that historic evidence shows to be directly linked up with ourselves, is the Cro-Magnon race that succeeded and was partly contemporaneous with the Neanderthalers, whom they would seem to have exterminated, as we find no evidence of their presence after this period.

This highly developed and artistic race, wholly modern in type, seems to appear suddenly in Western Europe at the close of the Mousterian period. They are the prehistoric people who painted those spirited, polychrome pictures of the animals of their times upon the walls and roofs of some of the caves of France and Spain, twenty-five to thirty-five thousand years ago. They are said to be the finest race physically that ever lived on this earth. Certainly, to judge by their skeletal remains, in general physique and in brain volume, no race, ancient or modern, has ever excelled them. They form a definite link between the prehistoric past and the present; for of the three great races that make up the peoples of Europe today one of them is believed to be largely composed of their direct descendants. This is the race known as the Mediterranean.

But although we cannot trace back with any degree of certainty at present, our relation to Palæolithic man beyond the Aurignacian or Cro-Magnon period, it must be admitted that our survey of these early types of men has brought out very clearly the relations which science claims exist between them and the higher apes. Unless this relationship be granted there is no reasonable explanation for the strange Simian characters manifested by the earliest types of them.

If man and the anthropoid apes are not descended from a common ancestor why, then, it may fairly be asked, do these early types of man exhibit so many markedly ape-like features? Why is it so difficult to determine whether some of them should be classed among the Hominidæ or among the Simiidæ? Our highest authorities are in doubt to this day whether Pithecanthropus of Java should be regarded as an ape, which had followed more closely the lines of human evolution than some of his fellows, or as a primitive man who had followed rather closely the lines of specialization taken by the apes, so indeterminate, so intermediate and so mixed are the physical characters it displays.

No one can view Pithecanthropus and Eoanthropus—not to mention the other primitive types—with open mind and doubt man's relation to the apes.

Accepting, then, this relation as too obvious, in the light of the facts which support it, to be denied, there remains now only to ask: Can we learn what the ancestor common to man and the higher apes was like? And is the statement made earlier in this chapter in accordance with the evidence we have been able to gather? Namely: that man is less specialized than the apes and must, therefore, follow more closely than they do, in his general cranial characters at least, the original type from which both have come?

A brief study of the accompanying plates will readily assure us that this is so. And if we had earlier remembered the significance of the biogenetic or recapitulative law formulated by von Baer years ago, no doubt would have been entertained concerning the relationship of the Piltdown mandible to the Piltdown skull; or that such modern-looking types as the High-terrace men could have preceded the low-browed chimpanzee-like Neanderthalers.

Instead of looking to the mature apes of today for the original type of Palæolithic man we should have

taken the skulls of their young into more serious consideration; for under the biogenetic law these must be closer to the ancestral type than are those of the more specialized mature forms. As was shown by the embryological evidence in the last chapter, and as the photographs here show, these in their cranial contours and general characters are much closer to the human than to the ape type; and to the Piltdown type than to the Javan type. We are justified, then, by this evidence in assuming that Eoanthropus represents more closely than does Pithecanthropus the earliest type of man.

And that the biogenetic law holds good here, and that the young ape and the Piltdown type represent most closely the ancient ancestral type of the higher Primates, as the writer has of late years maintained, the very recent discovery of the Taungs skull in Bechuanaland in South Africa most clearly demonstrates, photographs of which are here given in order that the reader may judge for himself.

This fossil has been named Australopithecus by its discoverer, Dr. Dart, and has aroused much interest in anthropological and palæontological circles, on account of its man-like appearance and its apparent extreme antiquity. It is estimated to belong to an age as far removed from that of Eoanthropus as his age is from ours. We are thus carried back a long way into the Tertiary, and may see in Australopithecus one of the earliest distinct man-ape types.

From its dimensions and from its general appearance it is easy to gather that it is the skull of an immature form. In its general contours and characters it is not greatly unlike that of Eoanthropus, except that it is much smaller and its brain volume much less, being about 600 c.c. only. It also seems to bear a fairly close resemblance to the skulls of the young apes of today. This is what we should expect under the biogenetic law. And while it distinctly favors the ape in its general characters, and particularly in its prognathism, it is not greatly unlike skulls of some of the backward races of today; there is a distinct suggestion of the human about it as its discoverer has pointed out.

In concluding, then, this brief survey of Palæolithic man, it may fairly be claimed, we think, that the evidence of man's physical evolution adduced in this chapter leads irresistibly to the conclusion that man and the higher apes are closely related, and also that the former is much less specialized than the latter and retains more closely than they do, many of the cranial characters possessed by the remote ancestor common to them both.

FIG. XI.

THE now famous Taungs skull from Bechuanaland, recently found in a limestone cliff of Early Pliocene or possibly late Miocene age. Prof. Elliot Smith thus writes of it: "The form of the forehead, the absence of the salient eyebrow ridges, the features of the jaws and teeth, the shape of the nose and orbits, the slenderness of the cheek-arches, and the harmonious proportions of head and face, all suggest the inference that this unmistakable ape reveals an early stage of the refinement that eventually led ages later to the attainment of human status." It shows, at any rate, the type of creature man must have sprung from. It is the oldest of the distinctly man-type apes.

CHAPTER XXII.

Vestigial Structures

IN THE preceding chapters we have sought to present some of the more obvious aspects of the evidence upon which the doctrine of organic evolution has been established; and it must be admitted by all unbiassed persons, that the cumulative force of this evidence is very great; so great indeed that no amount of the specious reasoning usually indulged in by the anti-evolutionist can successfully meet or refute it. For even if it be conceded that some few portions of this evidence may conceivably be interpreted in other than naturalistic terms, it remains undeniable that the major part of it is wholly without rational explanation or meaning, if considered apart from the point of view of an evolutionary process in nature.

But the class of evidence to be adduced in this and the following chapter is still more indisputable and of such a purely naturalistic character as to be absolutely meaningless and without any possible explanation, even the most labored and specious, if we attempt to interpret it in any other way than in terms of organic evolution; or refuse to admit a genetic relationship between the other members of the Primate order and man.

This evidence is drawn mainly from the presence of non-functioning and wholly useless vestigial organs or structures in the life-forms of today; and from the science of Serology or the "specificity" of blood.

Vestigial organs are relics of structures which are commonly functionless in the organism possessing them, and which from long disuse have become more or less atrophied and rudimentary; but which in the earlier ancestral forms of these organisms obviously served some useful purpose. Under the force of the law of heredity, scores of these structures are found lingering on in a rudimentary condition in the organisms of today. Nothing shows more plainly the evolutionary changes which have taken place in the past in the organic world than these same vestigial, non-functioning structures.

Attention was called, in our embryological discussion, to the fact that children are sometimes born with hairy bodies like those of the young apes; with webbed hands and feet, like those of a frog; and with a projecting tail. Quite recently it was reported that a child had been born in a New York hospital with a caudal appendage of this kind which had to be removed by a surgical operation. If the doctrine of evolution be rejected, and if man be not genetically related to lower forms of life, how comes it that he is occasionally born with an abnormal growth of hair all over his body, which bears a close resemblance to the hairy covering of the young ape; with webbed hands and feet like those of the frog; and with the base of his spinal column elongated into a distinct tail after the manner of the tailed animals.

Under a common-sense, naturalistic point of view the presence of these useless, abnormal structures can be reasonably and satisfactorily explained; but under the "Special Creation" theory of the anti-evolutionist, they are absolutely without rational explanation of any kind; and when, regarded from such a point of view can only detract from the dignity, power and wisdom of the Deity.

There are numerous other vestigial organs or rudimentary structures besides these. Any text book on Mor-

phology or Comparative Anatomy will furnish scores of them. According to Weidersheim, man himself has not less than 180 of these relics of the past within or upon him; most of which point to more primitive conditions of life and to his descent from lower forms.

In the 300 muscles we possess and are known to share with the Quadrumana, there are a number which are ordinarily functionless today; such for example as those in our outer ears. In other animals and even in some of the lower primates themselves, such as the baboon, the macacus and other monkeys, these are relatively large and in full functional use; but in man and the higher apes they are seen to have greatly dwindled in size, and are now ordinarily functionless.

It is well known that many animals are able to move their skin by means of subcutaneous muscles. We may often see the horse, for example, disturb the flies which irritate its body in this way. We, also, possess remnants of these muscles ourselves; some of which, such as those of the forehead, are still active, but the greater number of which have gone out of use. Most of these skin muscles still actively function in the monkeys and anthropoids.

There are many other of these vestigial muscles in our bodies some few of which certain persons are still able to use, and all of which present the closest homologies with normal muscles of the same kind in the Quadrumana and other mammals.

In the inner corner of our eyes there is a little pulpy mass to be seen. This is the relic or vestige of a membrane that in our remote ancestors formed a third, semi-transparent eye-lid known as the nictitating lid, such as we saw the birds had inherited from their reptilian ancestors, but which we no longer use or need. This same vestigial organ is found in all animals of the vertebrate class from the fish upwards to the mammals, in a more or less rudimentary condition. Our present eye-lids, which are later evolutionary structures, are better adapted for the sweeping of dust or other foreign substances from the eye-ball than was the more primitive nictitating membrane, and hence its vestigial form in ourselves and in the other mammals.

A study of our teeth reveals to us that degeneration is taking place in some of them, particularly in the third molars, our so-called "wisdom teeth." These in our remote ancestors were the biggest and strongest of the grinders. Today with most of us they are the smallest. Originally they had three fangs and five cusps. Today they normally possess but two of the former and four only of the latter. They vary, too, not only in their structure but also in the period of their development. They do not appear till we are well advanced in life and are usually the first to decay and disappear. They are certainly passing into a rudimentary condition.

A still more interesting and a more decidedly vestigial feature is seen in our eye-teeth or "canines," which has no possible explanation other than a naturalistic one. The roots of these teeth start much farther up or down, as the case may be, in our jaws than do any of the other teeth. There is absolutely no reason for this peculiarity at this stage of our development; and it is quite meaningless unless we see in it evidence of the fact that the canines of our remote ancestors required deeper and longer roots than did the other teeth, because of their more pronounced development and the consequent greater strain upon them.

That our canines were originally longer is shown by the fact that today they are seen to extend, in the jaws of many persons considerably beyond the level of the other teeth, sometimes being almost dog-like in appearance. We saw, too, that in the mandible of Piltdown man they were decidedly ape-like in their growth and apearance. We cannot

doubt, therefore, that this deep-rootedness of our eye-teeth when there is no longer a need for it, is a vestigial feature in them which has persisted down to the present day under the influence of the hereditary principle.

Then there is that rudimentary organ the vermiform appendix or prolongation of the colon, which has so often to be removed from us now-a-days on account of the trouble it creates.

All these and a host of other similar rudimentary organs witness to structures within us which in earlier times were useful and apparently necessary to some of our ancestors, and which are today still functioning in lower life-forms; but which, by reason of the evolutionary modifications that have taken place, or are even now taking place within us, are no longer necessary or useful to our selves.

Normally, man has 12 pairs of ribs; but occasionally a 13th rib appears. This suggests to the evolutionist that at one time in his bodily development man had, as most of the anthropoid apes today still have, an extra pair of ribs which he later lost, possibly as a result of taking the upright posture. The apparent loss of this 13th rib should gladden the hearts of the Fundamentalists who still take the story of the creation of Eve from a rib of Adam literally; only they ought to be told that one of the present-day man-apes, like man himself, has likewise normally only 12 pairs of ribs. What became of his 13th rib? Did an Eve for him spring from it?

But more interesting than an occasional 13th rib in the human body, and something much more difficult to explain away, is the appearance at times in man of a number of extra mammary glands. Ordinarily human beings possesses but two of these situated on the breast. Now, to the evolutionist, it becomes in this connection a highly confirmatory bit of evidence—but it must on the other hand be most perplexing and disturbing to the opponents of evolution—to learn that the mammary glands develop and go through the same phases in the embryo of man as they do in the embryo of all the other mammals. In both we may see what is called the "milk line" or "mammary ridge" appearing in the 6th week of development. This milk-line or ridge extends along each side of the body from the axilla or armpit to the groin. Along these ridges the nipples for suckling the young will later appear. In most cases the number of these nipples will be fairly proportionate to the number of young the female bears at one time. As many as sixteen nipples may appear or as few as two which is the normal number for man and the other primates. Yet it is a well-known fact that in about fifteen per cent of human beings one or more supernumerary nipples are to be found upon the body; and as high a number as sixteen have been known to appear at times, two of these being on the thigh.

How shall we explain the presence of these supernumerary organs in the human body if we deny an evolutionary process in nature? Why does the mammary ridge appear at all in the human embryo if it be not a recapitulative phase which records, under the operation of the law of heredity, an earlier ancestral condition, when our remote mammalian progenitors habitually gave birth to several offspring at the same time?

Regarded in this light both "milk-line" and supernumerary nipples are reasonably explained; but if man was created out of hand by a special act of Creation as the Fundamentalists would have us believe, and consequently can have no genetic relationship to the other mammals, why does his embryo go through exactly the same phases of development in respect of his mammary glands—not to mention other features—as do theirs; and why do these useless extra nipples appear upon his body? Before our opponents denounce and reject

the doctrine of evolution they ought to give us a satisfactory answer to these questions. They have never done this yet, and we do not see how they ever can.

But the strongest and clearest evidence offered, of the truth of evolution by the presence of vestigial structures, is that drawn from such highly-modified animals as the snakes, the whales and the members of the horse family. The rudimentary organs and relics found in some of these constitute the strongest and most signal proof of an evolutionary process that could be desired. The snakes are relatively modern creatures and have all been derived from earlier reptilian forms which possessed limbs. It is impossible to doubt this, for we find today the evidence of these former limbs in the remains of a pelvic girdle and in portions of the thigh and leg bones, in that region of their bodies where the pelvis and hind limbs are always found.

Thus the thread snake Glauconia, the worm-snake Typhlops, and the slow-worm Acontias all possess relics of this kind, in one phase of degeneration or another. In the python, and other allied forms, we find portions of the ilium—the anterior part of the pelvic arch—of the femur or thigh bone and of the tibia or leg bone and claws. What are these structures—all of which belong only to limbed-animals—doing within the body of the snake, if they are not relics of a former condition of life? It is impossible to explain them away apart from the doctrine of evolution. When the limbs have wholly disappeared as in the case of Typhlops and Acontias, and the remaining pelvic girdle is free from any attachment to the ribs or spinal column, what functional value can we conceive them to have? The only possible explanation of them is to say their presence is due to degenerate mutations or adaptational responses on the part of the snakes, to altered conditions in their lives.

That the snakes, or rather the forms ancestral to them, were animals with hind limbs like the other reptiles, is clear from the evidence we may gather from their embryological phases. In one of these phases the rudiments of the limbs formerly possessed by their ancestors are seen arising in the form of what is called "muscle-buds." These are identical with the same rudiments found in other embryos in which the limbs later develop. It seems impossible to satisfactorily explain the presence of these "buds," which in the snake embryo later disappear, if they do not represent earlier, anatomical characters in the ancestral history of the snakes. Indeed, they can be no more explained apart from evolution than can the presence of the gill-slits, the webbed fingers and toes, the hairy body and the tail of the human embryo.

Similar degenerate mutations or adaptational modifications are seen in the whale family. The Baleen whales have no teeth today, and, under the conditions of their present life and their mode of feeding, do not need them; yet their embryos have a full set. But the strange thing about these teeth is that they never even cut their way through the gums, and so can never function. What use, it may be asked, can teeth, cut or uncut, be to the whale's embryo? One fails to see how they can be of any more service to it than are the webbed fingers and toes, and branchial slits to the human embryo. Why then are they present? There is only one possible answer. They are vestigial organs, recapitulative ancestral phases, which occur in the embryo by virtue of the law of heredity, which is slow to let go what it has once acquired. By the same token rudimentary hairs are also found on the body of the young whale which disappear before it reaches maturity.

The present-day whales are sea mammals, live the life of fishes, and so do not need the hind limbs formerly possessed by their ancestors, are, indeed, better off without them;

and hence their disappearance. But that they once possessed them is perfectly clear from the fact that vestiges of them are found buried in the flesh of the whales of today just as we saw they were in the bodies of the snakes. We find remnants of the pelvis and the femur in all degrees of degeneration. In some whales the thigh-bone is represented by the merest relic buried in the flesh of the animals in the region of the pelvis. In others both pelvic-bone and thigh-bones are almost intact. What possible explanation for these varying vestigial structures can be given apart from the claim that the whale is a modified land animal whose ancestors resorted to an aquatic existence and in course of time lost their hind-limbs by degenerate mutation or adaptive response to their new conditions of life? There is none; and what clearer evidence could we ask of the truth of the evolutionary doctrine than is furnished by these relics in the whales and in the snakes?

But let us take another instance of this vestigial evidence; this time from the horse family. We saw in a former chapter that the horse, as at present constituted, is a one-toed animal, but which, notwithstanding showed clear signs of its descent from an earlier five-toed ancestor. That the splints or side bones in the horse's leg today are vestiges of earlier toes, becomes abundantly clear, apart from the evidence of Palæontology, by the fact that these splints sometimes bear distinct external, little hoofs which are suspended in the air at the side of the leg. Many cases of this development of the splints are known to us. History has recorded that Julius Cæsar possessed and rode a horse marked by this peculiar, vestigial structure.

Again the tail bones in a bird have no meaning or adequate explanation unless viewed in the light of the long, articulated tail seen in Archæopteryx and in the tails of its reptilian ancestors. Still another instance from the birds. In the embryo of the ostrich we find more toes present than appear later in the adult forms. Why should this be if these birds are not descended from an earlier five-toed ancestor?

The dew-claws of dogs, cattle, sheep, pigs, and other animals are only to be satisfactorily explained in the same way.

Before those who are opposed to the doctrine of organic evolution reject it and deny its validity they ought to furnish us with a satisfactory and reasonable explanation of these vestigial structures in man and the other life-forms. But this they have never done nor do we think they ever can do.

But enough has been said of these surviving relics of former conditions of life. In the next chapter we will briefly direct our attention to the evidence to be drawn from Serology or, to employ a more popular term, "blood tests".

CHAPTER XXIII.

Serology or Blood Tests

IF, in the last chapter, it was seen to be impossible under the theory of "Special Creation"—and, be it remembered, special creation is just as much a theory as organic evolution—to give a satisfactory explanation of the presence of vestigial structures or rudimentary organs in the animals of today and in man, it will be found to be still more difficult under this theory to account for the blood relationships which serology shows to exist between this species of animal and that; and more particularly between man and the other members of the Primate order. No theory but a naturalistic one, such as organic evolution, can possibly explain in a manner satisfactory to our reason, these genetic relationships disclosed by blood tests.

Serology is the science which treats of serums, of which we hear so much these days, and of the specific qualities discoverable in blood.

At first sight all blood seems to look very much alike, whether it comes from this animal or that, whether from a sheep or a cow, a monkey or a man; and ordinary chemical analysis fails to show any difference. Notwithstanding this apparent sameness, medical science was aware even before our present definite knowledge of the "specificity" of blood had been reached, that there must be important differences in the composition of blood; for experience had shown that a transfusion could not be made from an animal to a human being without serious injury, or even death, to the patient. It was clear, therefore, there must be a difference at least in human and other blood.

Today, we know from a long series of experiment, conducted by different investigators, that not only are there specific differences in the blood of man and nearly all the other animals —and the few exceptions to the rule are tremendously significant as we shall presently see—but that there are equally specific differences in the blood of the different groups or classes of animals themselves; and that these differences seem to be always proportionate to the nearness or remoteness of the genetic relationships descriptive zoology has led us to believe exist between them. It is this distinctive quality of blood which gives it its character of "specificity," as it is called. Even within the same group or family or race of animals, a specific difference in the character of the blood reveals itself. We have learned, for example, that it is very unsafe to make a blood transfusion from one human being to another without first testing the quality and character of the blood to be taken from the subject, and ascertaining that it corresponds in these particulars to the blood with which it is to be mixed. If this precaution be overlooked serious results may follow the transfusion. It may even cause the death of the patient. It has, in fact, been known to do this.

If, then, within the human family itself, we find such differences in blood, we would expect to find still greater ones between human blood and the blood of other animals. This is exactly what we do find. And we have also found that the injection of blood from an animal of one group or race into the system of an animal of another group or race will seriously affect the latter, even to the causing of its death.

Because of these peculiar properties of blood, it has been found that a number of definite results may be reached by means of blood reactions;

not the least valuable of which is the ascertaining of the degree of relationship existing between the different groups of animals found in the world today. It thus becomes a very valuable auxiliary in zoological classification; and herein lies its interest for the evolutionist.

By its means it is now possible to check up our descriptive lists and see if they are borne out by the blood reactions. This has already to a large extent been done with very gratifying results, the blood tests confirming in a truly remarkable manner the earlier zoological classifications. Only in a few instances has disagreement been found between the two systems.

Of these blood tests the best known and most widely practised are those employed by Doctor George H. F. Nuttall and his colleagues at the University of Cambridge. These experiments have been confirmed in large part by other independent investigators in different parts of the world, so that today they may be regarded as well-established facts of science.

There are several ways of bringing about these blood reactions, but we will consider here only one of them, and by preference the "precipitation method," usually employed by Nuttall; first, because of the large number of his tests—some 16,000 in all—and, second, because his tabulated results best lend themselves to presentation in an inquiry such as this.

The precipitation method of reaction is thus performed: Freshly-drawn blood is taken from some animal or a human being. This is now allowed to clot. Clotting occurs quickly if the blood be left standing in a dish or pan for a few minutes. When the clotting has taken place the watery portion at the bottom of the dish is drained off and set aside for future use. This almost colorless liquid is called "blood-serum." Let us suppose the blood in this instance was that of a human being, the serum would then be known as human serum. Let us further suppose the test we are about to make is to determine whether any particular specimen of blood or blood-stain is of human origin or not. This has often to be done in murder cases. We must first obtain some anti-human serum to act as precipitating agent in our test. This is done by injecting small quantities of the human serum we have prepared into the veins of some animal—say a rabbit or a guinea-pig, either of which animals is easily controlled—at short intervals of one or two days. The quantity of the human serum must be small enough not to cause the death of the animal; for being foreign serum this it would quickly do if injected too freely. This human serum will cause the formation in the animal's blood of what is called an anti-body. (We may perceive in this process the principle which underlies all our present-day inoculations.)

The animal is allowed to live for several days after the last injection. It is then killed, the blood taken from the body, allowed to clot, and then the serum is drained off and set aside. This serum thus obtained is known as anti-human serum and is a most valuable and extremely delicate test for determining the presence of human blood and for differentiating it from all other kinds of blood except that of the other Anthropoidea. This may be done whatever the condition of the blood; not only when it is fresh and liquid, but also when it is stale and dry, or when but the faintest trace of it is found. All that is required is to soak the specimen in a weak solution of common salt. Should it be dirty and associated with foreign substances, these impurities may be filtered out again and again, until the solution is as limpid and clear as spring water, without affecting the specificity or distinctive characters of the blood. These remain the same; and if the blood be human this fact will inevitably reveal itself by means of this delicate test if it be properly carried out.

A few drops of this anti-human serum poured into the solution will cause a clouding effect to appear

after a short interval, and when the reaction is completed a white precipitum will be formed and deposited at the bottom of the test tube. If the blood be not that of a human being the test invariably fails, no clouding appears and no precipitation takes place, with one remarkable and significant exception: This is when the solution contains the blood of some other member of the Primate order.

We may take the blood of any of our domestic animals or of any wild animal, and no reaction follows; but if the solution be made from the blood of one of the other Primates the reaction is seen to follow the same lines as in the case of human blood, with this single difference, namely: that the promptness and completeness of the reaction is always found to be in proportion to the genetic relationships otherwise known to exist between the members of the Primate order.

Thus it is found that the reaction from the blood of the man-apes is quick and prompt and commonly manifests itself in the following order: Gorilla first, chimpanzee second, orang-utan third, and gibbon fourth; less promptly and completely when we are dealing with the blood of the Old World monkeys, becoming progressively weaker and slower as we descend the Primate scale through the New World monkeys and marmosets to the lemurs, the lowest members of the order. With these latter we find the reaction very slow and the precipitation nil or almost so in a solution of ordinary strength.

These results bring out exactly the same degree of genetic relationship as our embryological, anatomical and palæontological investigations led us to believe existed between the members of the Primate order; thus offering strong supplementary proof of man's membership in this order and his close relationship to the man-apes.

As illustrating concisely and plainly the truth of this statement, the following tabulated results of a number of experiments conducted by Nuttall with anti-human and other sera are here set forth.

(A.) Anti-human precipitating serum tested against:	Per. Cent. Reaction.
34 specimens of human blood gave	100
8 specimens (3 species) of Anthropoid blood gave	100
36 specimens (26 species) of Old World monkeys' blood gave	92
13 specimens (9 species) of New World monkeys' blood gave	78
4 specimens (3 species) of Marmosets' blood gave	50
2 specimens (2 species) of Lemurs' blood gave	0

These reactions speak for themselves.

A close similarity to the reaction from anti-human serum is observed if we employ anti-simian sera instead; one set of experiments confirming the results of the other very remarkably, thus demonstrating beyond doubt the specificity of Primate blood.

(B.) Tests with Anti-Chimpanzee serum against:	Per Cent. Reaction.
3 specimens of human blood gave	100
3 specimens (2 species) of Anthropoid blood gave	100
23 specimens (19 species) of Old World monkeys' blood gave	65

(C.) Tests with Anti-Orang serum against:	Per Cent. Reaction.
23 specimens of human blood (4 races) gave	86
8 specimens of Anthropoid blood (3 species) gave	87
32 specimens of Old World monkeys' blood (23 species) gave	84
12 specimens of New World monkeys' blood (8 species) gave	42

(D.) Tests with Anti-Monkey (Cercopithecus) serum against	Per Cent. Reaction.
23 specimens of human blood (4 races) gave	87
8 specimens of Anthropoid blood (3 species) gave	75

35 specimens of Cercopithecidæ (O. W.) blood (24 species) gave	100
13 specimens of Cebidæ (N. W.) blood (9 species) gave	46
4 specimens of Marmosets (N.W.) blood (3 species) gave	25

This same anti-serum was used with the blood of the following groups of animals with these very significant low percentage results:

	Per Cent. Reaction.
29 Chiroptera	0
12 Insectivora	0
95 Carnivora	2
62 Rodentia	0
67 Ungulata	1
3 Cetacea	0
13 Edentata	0
26 Marsupalia	8
271 Aves (incl. 3 eggs)	0
45 Reptilia	0
9 Amphibia	0
14 Pices	0

Nuttall remarks of these monkey-serum tests: "The results will be seen to correspond to those obtained with the preceding anti-sera, only that the reactions among the Cercopithecidæ (Old World monkeys) form the majority of the marked reactions." This is what one would expect, as the serum comes from them.

The outstanding feature about these tests is the marked specificity of the blood of the Primates; anti-Primate sera having little or no effect, when solutions of ordinary testing strength are used, upon the blood of other groups of animals.

Experiments made with anti-sera from any of these bring out the same specific characters in blood. The reactions manifested are always proportionate in strength to the closeness of the genetic relationship existing between the animal whose blood is being tested and the animal from which the serum comes. The closer the blood-tie, the stronger and quicker the reaction. The remoter the blood-tie, the weaker and slower the reaction.

This is admirably brought out in the following set of experiments:

Anti-Sheep Serum	Per Cent.
Sheep	100
Ox	80
Antelope	50
Hog-deer	47
Reindeer	30
Pig	20
Horse	16
Cat	12
Dog	7
Wallaby	5

Anti-Pig Serum.	Per Cent.
Pig	100
Horse	16
Hog-deer	14
Cat	14
Dog	13
Sheep	13
Wallaby	5

These results show very clearly that there are measurable differences in the degrees of reaction. The percentage in each case is based upon the amount of precipitation obtained under similar conditions.

It may be stated in this connection that if very strong solutions are used in these tests, sufficient care taken over them, and time enough allowed for the precipitation, the varying degrees of relationship, which descriptive zoology declares exist between the different orders of animals on the earth today, can in every case be successfully demonstrated and worked out on a percentage basis similar to those which have been given here.

The degrees of relationship between the members of the Primate order are seen to be very clearly brought out in these experiments. In the same way anti-carnivore sera show a preponderance of large reactions among the bloods of the Carnivora as distinguished from other Mammalia; the maximum reactions invariably taking place amongst those forms which we commonly regard as related to one another.

Anti-pig serum gives maximum reactions only with the bloods of other species of the same family, as we have seen. It gives slighter reactions with blood of ruminants and with camels, and a slight reaction with the blood of whales. Conversely anti-whale serum gives slight reactions with pig-blood. and strong reactions with the blood of other whales.

From other lines of evidence conclusions had been drawn by zoologists that genetic relationships existed between the llama and the camel. These

conclusions are borne out by the blood test, anti-llama serum giving a fair reaction with the blood of the camel and vice versa.

The close relationship believed to exist between the deer family, the antelopes, sheep, goats, oxen, etc., are also clearly demonstrated by the specific characters of their blood under these tests, as the example given above shows.

Among the reptiles anti-lizard serum gives maximum results only with the blood of other lizards and moderate reactions with the blood of snakes.

Experiments with anti-reptilian sera disclose the fact that there is a close relationship between lizards and snakes, and between turtles and crocodiles; and also that birds are more nearly related to the turtle-crocodile series than to the lizard-snake series. Here again we find confirmation of our earlier palæontological studies and conclusions. We know that the snake-form has been many times independently evolved by different families of lizards.

Nuttall tells us that tests were made by means of anti-sera for the fowl and the ostrich, upon 792 and 649 bloods respectively, and that they demonstrated a similarity in blood composition of all birds. These results are in sharp contrast with what has been observed with mammalian bloods when acted upon by anti-mammalian sera. They would indicate, therefore, that birds, as a group, are more nearly related to each other than are the mammals as a group. This is exactly what might have been anticipated from palæontological evidence.

Taking Nuttall's 16,000 blood tests as a whole, it has to be admitted that they bring the strongest confirmation of the genetic relationship existing between the various groups of animals, and especially between those of the same family and order. These experiments form the final, consummate links in the long chain of evidence science has gathered since Darwin's time in support of his great generalization; and when taken in conjunction with the vestigial structures considered in the preceding chapter, should remove the last lingering doubt from the mind of anyone capable of evaluating scientific evidence, concerning the validity of the doctrine of organic evolution and the descent of man from lower life-forms.

CHAPTER XXIV.

The "Factors" of Evolution

UP TO this point in our inquiry we have been dealing entirely with the "fact" of organic evolution. Concerning this, as has been repeatedly pointed out, all biologists are in full agreement. No doubt at all exists in their minds about the fact or principle of organic evolution itself, notwithstanding the statements to the contrary which are constantly being made by anti-evolutionists.

Every year that has passed since the publication of Darwin's "Origin of Species" has brought additional proof of the truth of his illuminating doctrine, until today no scientific fact is so well-attested or so firmly-established as that of organic evolution.

Differences of opinion among biologists arise only when they are dealing with the "factors" of organic evolution; that is with the causes or agencies which underlie and bring about the changes and mutations that we know by the palæontological record to have taken place in the organic world in the past, or which we may see still taking place there today.

With respect to these there is admittedly not the same unanimity of opinion among them; and from what we have learned of the subtle nature of these factors this could hardly be expected. The whole question has proved to be an exceedingly complicated and perplexing one. It bristles from end to end with natural difficulties; and because it is susceptible of approach and investigation from more than one angle it has come about that division of opinion has arisen among biologists according as they have regarded the subject from this or that view-point, or laid stress upon this or that aspect of it.

Moreover many matters that were taken for granted when Darwin's "Origin of Species," first appeared have since become questions of lively de bate and contention. Many of these still remain unsettled.

Thus, for example, Darwin, following Lamarck, never questioned the view then commonly held, that all modifications or new characters appearing in, or acquired by, an organism could be transmitted to its offspring, and so be perpetuated. Such transmission he took for granted as Lamarck had before him.

The theory of evolution as conceived by Darwin contained within it three great principles or factors: First, Variation; second, The Struggle for Existence; third, Natural Selection

Variability in organic forms was seen by Darwin to be a fundamental fact in the life-realm and upon this he founded his great generalization. Under the operation of the law of Variation the offspring of an organism exhibited a tendency to depart from the parental type. If the change or modification thus arising happened to be favorable to the offspring in the struggle for existence it gave them an advantage over less-favored forms. The principle of Natural Selection, or as it is otherwise expressed, the Survival of the Fittest, here operating would ensure their survival and perpetuation, while the others would pass out of existence.

As Darwin saw it, plants and animals, because of their remarkable ability to quickly multiply and propagate themselves in their natural state, are subject to an incessant and keen struggle for existence. There is hardly a single organism we know whose offspring, if all were permitted to live, would not in a few generations fill the whole

world and choke out all other life-forms.

We saw in an earlier chapter how one little Slipper animalcule could alone, in five years if all its progeny had been permitted to live, have brought into being a volume of protoplasm 10 times greater than the volume of the whole globe. Life in both plant and animal form, under natural conditions is exceedingly insurgent. Life-forms multiply prodigiously. The number of seeds produced by some of the more prolific plants reach enormous figures. A tobacco plant will produce in one season as many as 360,000; some weeds as many as a half million. Darwin found that the capsule of the orchid Maxillaria produced 1,750,000 seeds and Acropera 74,000,000 per plant. Bower has pointed out the marvellous productivity of ferns. The common Shield Fern is capable of producing in a single season from 50,000,000 to 100,000,000 spores; and a single leaf of the genus Arata 2,800,000; whilst Angiopleris has been known to produce 4,000,000,000 spores from one leaf.

A single microbe, Bacillus subtilis, can divide itself and become two in twenty minutes; and, if this binary fission be permitted to go on unchecked, a single one of these bacilli could produce 134,000,000 microbes overnight. A codfish is capable of laying 4,500,000 eggs in a single season. The American oyster lays on an average 16,000,000 eggs. If all these hatched out and produced oysters, the progeny of a single one would in five generations give rise to the incredible number of 66, followed by 33 naughts, and the mass of shells thus produced would be eight times as great as the mass of the earth.

In nature, under such tremendous productivity, it is clear that every individual life-form must be subjected to a fierce competition not only with the members of its own species, but with every other organism. The struggle for existence is thus very sharp and bitter; and only those organisms which have gained some advantage over their fellows can possibly maintain their existence and perpetuate their kind. All favorable variations, therefore, no matter how slight, arising in an organism, give it a decided advantage in the life-struggle over those not so favorably modified.

Thus Natural Selection working upon advantageous variations, was conceived by Darwin to be the efficient cause in the production and perpetuation of new forms. Variation in a given direction once arising, he held, would continue in that direction and thus each generation would contribute its share of favorable changes however small; the sum total of which would, in course of time, result in the evolution of new characters and new species.

The essence of the doctrine of organic evolution in the Darwinian sense, is just this: That small, even infinitesimal, changes or variations carried on continuously from generation to generation over long periods of time would in the end result in new and distinct species. This is the doctrine of organic evolution as enunciated by Darwin, and this in brief is his conception of the origin of species.

But, as all students of evolution now know, this view no longer stands alone. It shares the field today with a number of others.

One of the best known of these is the "Mutation Theory," otherwise known as the doctrine of "Discontinuous Evolution". This veiw regards evolution as proceeding by sudden leaps and bounds rather than by the slow, continuous modifications favored by Darwin.

The outstanding protagonists of the "Mutation Theory" are de Vries in Holland, Morgan in America and Bateson in England.

This concept of the evolutionary process is based upon the fact that conspicuous mutations appear at times suddenly in plants and animals; and that these often display characters so strange and distinctive as to force us

to regard them as new forms or species. De Vries' Evening Primrose, referred to in the second chapter, is a case in point. But a still more characteristic instance is the way in which the "Ancon" breed of sheep came into existence. This was brought about in the following manner:

There was a farmer living in one of the New England States a few generations ago named Ancon. He possessed a flock of long-legged sheep, the only type then known in that part of the country. These sheep gave their owners great trouble to keep them within their fields, their long legs making it easy for them to leap the fences. Ancon going through his flock one day with a neighbor in lambing time, discovered that one of his ewes had dropped a strange looking lamb quite unlike any of the others. It was characterized by a long, otter-like body and extremely short legs.

Regarding it as a monstrosity he was about to knock it on the head and put it out of existence, when his neighbor checked him and suggested that as the creature was a ram lamb he should keep it and breed with it; and in that way he might produce a new, short-legged type of sheep which would be more easily kept within bounds.

Favoring the suggestion Ancon kept the lamb and bred with it, and in the course of a few years produced a distinctly new type of short-legged sheep. This became the favorite breed in that part of the country until the introduction later of the merino sheep, whose superior wool and equally quiet habits caused it to oust and replace the coarse-wooled Ancon breed.

Darwin, while admitting the possibility of new types arising in this way, remained of the opinion that the evolution of new forms or species had been by way of slow but continuous and progressive changes over long periods of time, rather than by sudden saltations; that under natural conditions discontinuous evolution of this kind rarely if ever occurred; and that such mutations of the kind as we had knowledge of were most probably due to influences arising out of domestication and artificial conditions of life. De Vries, while still holding that new forms might and did at times suddenly arise in nature, was inclined upon further study of the subject to admit that evolution probably worked in the main by the Darwinian method rather than by sudden and sporadic leaps; a view that is strongly supported by the palæontological record, which certainly seems to reveal to us a long succession of slowly-changing forms, gradually advancing in complexity of structure, higher organization and increased functional scope.

Since de Vries' experiments with the Evening Primrose, however, Morgan, Bateson and other investigators have shown that sudden mutations have probably played a more important part in the evolutionary process than Darwin was inclined to admit; and today it is pretty generally conceded by biologists that both views must be taken into consideration whenever the question of the origin of species comes under discussion.

As will readily be seen there is no great opposition between "Continuous" and "Discontinuous" evolution. The two concepts are merely two different ways of accounting for the same thing—the rise of new forms or species. The latter accepts equally with the former the fact of evolution itself. There is no question on this point between the two schools of opinion.

And so it is with all the other views propounded. Not one of them calls in question the fundamental principle of evolution. They deal only with Darwin's conception of the causes which lie at the back of the evolutionary process. His critics mostly sought to add to his theory; to supply what it appeared to them to be lacking in; to strengthen it at the points where it seemed to be weak. Their criticisms have thus been on the

whole constructive rather than destructive; a point which seems to have been entirely overlooked or misrepresented by those opponents of evolution who are so fond of declaring that Darwinism has no place in modern biology.

This is nowhere more plainly shown than in August Weismann's theory of "Germinal Selection and the Continuity of the Germ-plasm". Weismann was one of Darwin's most brilliant disciples and an outstanding figure in biology in the last century. His study of the law of Heredity led him to take views concerning the origin of species, and particularly the transmission of "acquired characters," fundamentally different from those held by either Darwin or Lamarck; and as there is just now a strong tendency on the part of some of the younger biologists to return to a mod ified form of Lamarckism it may be well here to briefly outline the views held by Lamarck on these two points.

The key-note of Lamarck's theory of the origin of species lies in the term "Adaptation," in other words in the adaptive response made by the organism to the circumstances or changing conditions of its environment. According to him new functions and new structures evolved as the needs of the organism called them forth. He conceived that the initial urge towards change came from without the organism and not from within; and that new functions and characters thus acquired in response to this urge were thereafter transmissible and wholly governed by the principle of "Use and Disuse".

Thus for example, the long neck of the present-day giraffe might be conceived to have arisen from a change in its habit of securing its food. A lack of its usual food supply may have caused it to seek its sustenance from the foliage of the trees over its head rather than from the ground or from low bushes. Such a habit once engendered would have a tendency to elongate its neck; and each generation passing on to the next its own additional growth in this direction, the final result would be the evolution of its present long neck. The loss of the hind-legs of the whales and the limbs of the snakes may be regarded as illustrating how "Disuse" acts. And while the long neck of the giraffe most probably was evolved quite otherwise than as here suggested by Lamarck, there can be little doubt, we think, that the adaptive responses of organisms to environmental conditions and changes have played an important part in organic evolution, though not, perhaps, exactly along the lines imagined by Lamarck.

We saw instances, for example, of the influence upon function of changes in environment, in the methods of reproduction adopted by certain frogs and salamanders, in an earlier chapter; and recent experiments by Kammerer, the Austrian biologist and others, have shown clearly that adaptive responses to altered conditions of life may and do result in the appearance of deep-seated bodily modifications; and that these are transmissible to the next generation. We will speak of some of these experiments a little later.

Darwin rather scoffingly rejected this theory of the origin of species in favor of his own, namely: Natural Selection.

Taking the tendency which he observed in organisms to vary—which Lamarck seems to have overlooked—and seeing it controlled and directed by Natural Selection, he erected upon this the doctrine which we now associate with his name.

But "Natural Selection," as a causal agency in evolution, as Weismann was at pains to point out, suffered from a fundamental defect. It failed to inform us how or why variations arose. Natural Selection, it was shown, could not originate new characters. It could only select and favor them after they had once arisen.

Under Darwin's theory of evolution the causal basis of variation remained unexplained; and Weismann early

saw that no substantial progress in our knowledge of the evolutionary process could be made until we had learned something more concerning the underlying causes of Variation and the physical basis of Heredity; and he set himself the task of investigating the problem of evolution from these points of view.

His major contributions to the doctrine of organic evolution were his two great theories of "Germinal Selection" and the "Continuity of the Germ-Plasm". His concept of "Germinal Selection" does not really run counter to Darwin's "Natural Selection" as has sometimes been stated. It rather augments and supports it by supplying just those causal elements it was lacking in. Darwin gave us Natural Selection working on spontaneous Germinal Variation, without indicating how this variation arose. Weismann stepped in and gave us the alternative or supplementary concept of "Germinal Selection' working upon the principle of germinal continuity and independence of the germ-plasm. It is in this second concept only that we find any conflict arising between himself and Darwin, and Lamarck. He held that the germinal material, or germ-plasm as he called it, which starts the offspring of any organism owes its virtue to the fact that it is materially continuous with the germinal matter from which the parent or parents arose; and that in this way there is an unbroken continuity of generation.

He argued thus: In the development of the individual a part of the germ-plasm contained in the parent egg-cell is not used up in the construction of the body of the offspring, but is reserved unchanged for the formation of the germ-cells in the following generation. Under this view the parent is not regarded as the producer of its own offspring but rather as the guardian or trustee of the germ-plasm from which the offspring under suitable conditions will arise. This germ-plasm is thought to lie in the nucleus of the life-cell, and is identified with the chromosomes of the nucleus. In reproduction this germ-plasm is set aside and located in the sex-glands, where it is supposed to remain, quite free from the vicissitudes of the body cells, till the period of sexual maturity of the individual.

Weismann looked upon the somatic or body cells as separate and distinct from, and less complex than, the germ-cells, and as lacking the power of reproduction which was the peculiar property of the germ-cell alone. With him the germ-plasm was the material basis of heredity, the carrier or medium by which our heritable qualities are passed on. He held that all new characters which arise in the evolutionary process are due to releases of the inherent, potential power of the germ-cells; that the earliest primordial germ-cell had inherent within it all the possibilities of organic evolution.

It follows as a natural corollary from this that any changes or modifications of the body-cells taking place during the life of the individual are not transmissible, the offspring inheriting only from the germ-cell and not from the body-cells, the chromosomes being alone the carriers of heredity.

Subsequent researches into the nature of the nuclear elements and of the part played in inheritance by the chromosomes indicate that Weismann's theory of heredity has behind it a substantial background of truth; but that in denying the possibility of the somatic or body cells influencing in any way the germplasm, or having any reproductive or regenerative powers, he clearly fell into the error of overstating his case and went beyond the facts.

We saw in Chapter X. how strong were the regenerative powers of some of the lower life-forms; that Child, for example, was able to bring into existence new fully-formed planarians from small bits of these creatures; and that Hydra could renew itself from the tiniest particle of its

own body that had been strained through a cheese-cloth.

It is undeniable that the more lowly life-forms, both plant and animal, possess this power of reconstructing lost parts and of renewing themselves. Exactly to what extent this regenerative power is latent in the somatic cells of the higher life-forms has never yet been definitely demonstrated; but the case of the stork regenerating the lost portion of its bill, cited in the tenth chapter, would seem to show that the somatic-cells retain potentially the powers of the original germ-cell from which they are derived; and that in certain abnormal circumstances these latent powers become active and manifest themselves in relatively highly-organized life-forms.

The greatest opposition to Weismann's germ-cell theory, which has practically dominated biology for nearly two generations, comes from physiologists. They are not willing to admit that the germ-cells are so absolutely differentiated and insulated from the body-cells, or vice versa, as Weismann claimed. Child has pointed out that in some of his experiments certain somatic cells, after they had become distinctly differentiated into muscle-cells, lost this definite character and returned to a germinal condition.

Now it becomes quite clear that if this kind of reversion on the part of differentiated cells can take place—and on this point there appears to be no doubt—it is quite conceivable and possible that new germ-cells might arise from soma-cells in this manner; and thus a mechanism or way would be provided for the transmission of acquired bodily characters, or for the effects of Use and Disuse.

We know that among plants this can and does come to pass. Begonia, for instance, can reproduce itself from the smallest part of one of its own leaves, and the leaves of many other kinds of plants can do the same. We have therefore to admit in the case of these plants either that the leaf-tissues contain undifferentiated germ-plasm or that soma-cells can give rise to germ-cells. And when we leave the world of plants and enter the animal world, Kammerer's experiments with frogs, newts, salamanders and ascidians make it very clear that the same power lies in the soma-cells of animals.

Kammerer belongs to that school of biologists who believe that environment has more to do with the calling forth of new functions and bodily modifications, that are of a transmissible nature, than Weismann's theory of the independence and insulation of the germ-plasm admits; and he set himself the task of proving his contention.

The most noteworthy of his experiments along these lines include the restoration of the lost vision of the blind newts; changes in the coloration of certain salamanders; and modifications in the tissues of the organs of sea-squirts; all of which were shown to be heritable by the offspring of these animals in the following generation.

The newt Proteus is blind by nature because of its life-habits. It passes its existence in dark subterranean caverns. Kammerer, by alternately exposing some of these animals to ordinary sunlight and to artificial light (red) succeeded in redeveloping both their eyes and their sight. He found that by interbreeding these modified newts, their offspring in the first generation possessed normal eyes and vision. These cavern newts had inherited blindness from a long line of ancestors and this lack of eyes and sight was thus clearly a transmissible quality and could only have arisen from non-use, unless we suppose they were specially created sightless for existence in dark caverns. If we take this view then Kammerer's experiment shows conclusively that altered conditions of life can change the organs of the body and that these changes can be transmitted to and inherited by the offspring.

But Weismannians are evolutionists

and would never allow special Creation of this kind for a moment. Neither would they allow the case to be one of acquisition of new characters; but merely the restoration of a lost one. The remote ancestors of Proteus were for them creatures with normal eyes and vision.

But in taking this position they seem to have lost sight of the fact that they are hanging themselves on the other horn of the dilemma. For it must necessarily follow that if Proteus be descended from newts which originally possessed normal eyes and vision, the modern sightless-newts must inherit sightlessness in each generation. There has thus been a transmission here of blindness, which on their own showing was not an original characteristic but an acquired one.

Proteus was clearly either brought originally into existence eye-less and blind, or it possessed eyes and sight like other animals. If the former view be held then by gaining eyes and sight, these animals had acquired new characters which they were able to pass on to their offspring. If the latter view be taken then they had transmitted the acquired character of blindness to their offspring. Thus whichever way one looks at the matter there is no escape from the conclusion that there has been an acquisition of new characters, which in each case have been transmitted to the next generation.

But, Kammerer was not content to rest his claims on one set of experiments alone; he undertook others; this time with Salamanders as subjects.

The Fire Salamander is normally inky black in color with yellow markings consisting of irregularly distributed yellow spots. Now if these spotted salamanders be kept in an environment with a black background, that is, in black surroundings, these yellow spots in a few years gradually disappear and the creatures become wholly black; thus showing that external conditions can affect the coloration of their bodies. Conversely if they are kept in a yellow environment the yellow spots are seen to melt into each other, and in a few years yellow becomes the dominant color of the animal's body. By interbreeding black with black and yellow with yellow it was shown that the young of these modified salamanders inherited the newly acquired color characters of their parents and passed them on likewise to their progeny.

Surely we have here a clear case of the acquisition, transmission and inheritance of new characters.

But, Kammerer was still not satisfied. Desiring to remove all possible doubt about the matter he instituted another set of experiments, this time with Siona intestinalis, one of the ascidians or sea-squirts. This animal has a habit of anchoring itself to the bottom of the sea by its stolons which are very like the "holdfasts" of the sea-weed. Its outstanding features are two siphon-like organs which extend from the head of its cylindrical body. The longer of these siphons is the oral or inhalant one; the shorter is the anal or exhalant one. It draws in the water with the one and emits it through the other after extracting the nourishing particles it contains. Low down in its body lie the intestines and the generative organs. These latter consist of a hermaphrodite gland, Siona being a bisexual animal.

This creature has astonishing regenerative powers, and lends itself readily to experiments of the kind Kammerer contemplated. Thus if the tops of the siphons be cut off they speedily grow again becoming a little longer than before. Repeated amputations on the same specimen finally resulted in an elongation of the tubes much beyond the normal length, the successive new growths exhibiting a jointed appearance.

By breeding with these modified specimens it was found that the offspring in the next generation had siphons of abnormal length, but that the jointed features seen in the parent

had in the young forms been smoothed out.

Here again there seems to be a clear case of the acquisition and transmission of new characters.

The Weismannian school of opinion met this new experiment with the objection that the transmission of the elongated siphons to the offspring might be accounted for by regarding the relation between the soma-cells and germ-plasm as not yet fully and entirely severed; that the insulation of the latter from the former was imperfect in this instance; and thus the germ-plasm had been affected by the bodily mutilation and so was able to pass on the modification to the offspring. In other words they would not allow that the independence of the germ-plasm claimed by Weismann had been in any way impugned by these experiments.

To prove that the transmission of the elongated siphons was not brought about, as his opponents claimed, by the intervention of the germ-plasm stored in the generative organs, Kammerer now amputated the whole of the lower part of the sea-squirt containing the generative organs, leaving to the mutilated creature only that part of its body which carried the elongated siphons.

From this upper portion the specimen reconstructed itself afresh, growing a new lower part with new intestines and new generative organs; and when later this regenerated creature produced young it was found that they had inherited the elongated siphons of the parent as before.

These experiments seem to show conclusively that all the powers possessed by the germplasm lie dormant in every cell of the body, and can at times and under certain unusual conditions be called forth and brought into activity. When we remember that every somatic-cell of which the body is composed, has been derived from the original germ-cell by division of its substance, there is nothing unreasonable or impossible in this view of the matter; indeed it does not seem reasonable to expect that it should be otherwise.

If these conclusions be granted, as it seems they must be, then it follows as a natural corollary that transmission of acquired characters can and does take place; and that Weismann went too far in declaring that no bodily modifications arising from without can be passed on.

It should be added that these experiments of Kammerer do not stand alone. Many similar experiments have been carried out by other investigators; and some at least of Kammerer's experiments have been confirmed by Durkhem and Pavlov. Other experiments along somewhat different lines have also been carried out. Thus Doctors Guyer and Smith instituted a series of experiments of their own that appear to lead very decidedly to the conclusion that there is a way or mechanism by which the germ-plasm or heredity material may be modified by external agencies, as well as by the spontaneous changes from within postulated by Weismann. Guyer himself thus remarks in this connection: "No one today, qualified by his knowledge of embryology and genetics to the right of an opinion, would, I think, deny that the new organism is in the main the expression of what was in the germ-line, rather than what it got directly from the body of its parents; but does this fact necessarily carry with it the implication that the germ is insusceptible to modification from without? Is not the serum of organisms possessing blood or lymph an excellent medium through which external influences may operate upon it? Is it not more reasonable to postulate the origination of germinal changes through some such mechanism as this than to attribute it to mysterious 'spontaneous changes?"

The experiments of Guyer and Smith were carried on with various kinds of Sera. Thus, for example, they took the lenses of newly-killed rabbits and pulped them thoroughly in a mortar and diluted the pulp with

normal saline solution. A small quantity of this immulsion was then injected intraperitoneally or intravenously into each of several fowls. Four or five weekly treatments with this lens-immulsion were given. A week or so after the last injection the blood-serum of one or more of these fowls was used for injection into pregnant rabbits.

The rabbits had been so bred as to have the young advanced to about the tenth day of pregnancy; since from the tenth to the thirteenth day seems to be a particularly important period in the development of the lens. It is at that period growing rapidly and is then surrounded by a rich network of blood-vessels that later disappear. A certain quantity of this prepared fowl-serum, was injected at intervals into the veins of the pregnant rabbits. Several of these died from the effects of the serum and many of the young were killed in utero. But of sixty-one surviving young from mothers so treated, four had one or both eyes conspicuously affected and five others had eyes clearly abnormal; and it was found later that many of those which in the earlier period of their lives had seemed normal, developed defects in the lens or other parts of their eyes.

That these defects in the eyes of the young rabbits were true inheritances was proved by mating defective-eyed males with normal females unrelated to the stock used for the experiments.

The first generation produced by this crossing all had normal eyes; but when females from this generation were mated with defective-eyed males again the resultant offspring were defective-eyed.

As pointed out by Guyer it is obvious these defective characters could only have been conveyed through the germ-cells of the male and therefore the abnormality is an example of true inheritance. He further remarks: 'The point I wish to emphasize is that a certain specific effect has been produced; and, what is of greater moment, once the condition is established it may not be merely transmitted but inherited. Whether the lens of the uterine young is first changed and then in turn induces a change in lens-producing antecedents in the germ-cells of these young, or whether the specific antibody simultaneously affects the eyes and the germ-cells of the young, is not clear. In any event it is evident that there is some constitutional identity between the substance of the mature organ in question and the material antecedents of such an organ as it exists in the germ.

Biologically considered the most significant fact is that specific antibodies can induce specific modifications in the germ-cell. . . . Truly one may pronounce that social complex of reciprocating individuals termed cells, which make up an organism, "members one of another." And with all these co-operative activities of the various parts of the body it is inconceiveable to me, at least, that the germ-cells, bathed in the same fluid, nourished with the same food, stand wholly apart.

May we not surmise, then, that as regards inheritance and evolution, Lamarck was not wholly in error when he stressed the importance of use and disuse of a part, or of modifications due to environmental change, in altering the course of the hereditary stream, particularly if we conceive of these influences as being prolonged, possibly over many generations? Have we not in the Serological mechanism of the body of animals an adequate means for the incitement of the germinal changes which underlie certain aspects of Evolution"?

This very reasonable conclusion reached by Guyer, it may be added, receives strong support from a long series of other, more or less, similar experiments. And while Weismann's main concept of the germ-plasm, as the material basis by which our hereditable qualities and characters are passed on, remains unimpaired and very rightly still holds the biological field; it would seem that his second-

ary theory of the independence and insulation of the germ-plasm from the other cells of the body can no longer be maintained without considerable qualification.

It is in questions of this kind that differences of opinion arise among biologists; and one can see that in dealing with this aspect of the evolutionary problem such differences from the very nature of the subject, are almost inevitable.

But as our modern experimental methods come more and more to replace the theoretical methods of the past, as they are now fast doing, many if not all of these differences will gradually disappear as our knowledge increases and we get a clearer insight into the actuating factors which underlie organic evolution.

Of the several other schools of opinion which share the field of biology with Darwinism, there is one in particular we must briefly consider here, because of the high importance generally attached to it and because of the several weighty implications it carries. This is Mendelism. So many extravagant claims have been made for it that it has become difficult, quite apart from the intricate nature of the subject itself, for the lay mind to get a clear or just appreciation of what it has really contributed towards the solution of the evolutionary problem.

Few subjects in biology would appear to have given rise to more misstatements and unjustifiable conclusions than Mendelism. Over zealous advocates of this school of thought have made all kinds of claims for it, declaring it to be capable, amongst other things, of revealing to us all the secrets of heredity; and anti-evolutionists have asserted that it completely refutes Darwinism by demonstrating the unalterable fixity of species.

Both statements are equally far from the truth. For while it has thrown much new light upon certain special aspects of inheritance, it has by no means taught us all there is to know about the problem of heredity; nor has it demonstrated in the smallest degree the immutability of species.

Rightly considered Mendelism has very litttle direct bearing upon the evolutionary problem itself. It deals rather with the subsidiary problems arising out of hybridization or the crossing of stocks. As the distinguished Danish geneticist, Johannsen, has recently pointed out, Mendelism is mainly concerned with abnormal variation in hybrids; not with the general problem of inheritance or with the evolutionary process as such.

Like Weismann's concept of the germ-plasm, it does not conflict with Darwinism; it supplements it by throwing valuable light upon the part played by the chromosomes in certain limited cases of heredity.

Mendel was a contemporary of Darwin and published an account of his experiments a few years (1886) after the first appearance of the "Origin of Species". But the interest which Darwin's work evoked, and the controversies which grew out of it, completely overshadowed Mendel's discovery and it remained unnoticed, buried in the proceedings of a learned society of Bruun, till the beginning of the present century, when the same discovery was independently made by three other botanists—de Vries, Correns, and Tschermak.

This discovery, claimed by some enthusiastic Mendelians as the greatest that was ever made in biological science, has since become known as Mendel's Law, though the Mendelism of today has gone far beyond anything Mendel could have imagined in his time.

Mendel was an abbot of Bruun and devoted much of his leisure to the cultivation of flowers. In this pursuit he became interested in the crossing of stocks and in the inbreeding of the hybrids resulting therefrom, and sought to discover the law underlying inheritance as manifested in hybrids or crossed varieties of plants. He selected for his experi-

ments the common edible pea (Pisum sativum) which is a self-fertilizing plant and therefore very suitable for the experiments Mendel contemplated.

Peas, like other organisms, have certain marked and constant characters. Mendel noted a number of these. Some peas he found were round and smooth, others were wrinkled and pitted; some were yellow in color, others were orange or green; in some varieties the plants were tall, in others short.

By experimenting with one character at a time, in each of the crossed varieties, he discovered that these particular characters were constant and transmissible and never seemingly interfused or blended together.

The offspring always exhibited either one character or the other, no intermediate or blended forms ever appeared.

The reason for this he discovered was that in the crossing, one of the pair of characters always overshadowed and dominated the other so that for the time being only one of them appeared in the offspring, the other being swamped or hidden. This phenomenon he called the Law of Dominance; and the character that appeared in the offspring of the first generation to the exclusion of the other he called the "dominant," and the suppressed one he termed the "recessive" character. An illustration will make this law of Dominance clear. Tall-stemmed peas were crossed with dwarf-stemmed peas; that is to say one variety was fertilized with the pollen of the other. When the seed resulting from this cross was sown, the plants were found to be all tall; no blend or intermediate forms appeared. Tallness was thus seen to be the dominant character and dwarfness the recessive character; this latter quality being entirely masked or hidden in the first generation.

But now note what happens in the second generation when the plants were again self-fertilized. It was found that a segregation or separation of the two original characters took place in the following ratios: Approximately 25 per cent. of dwarf plants appeared which were found to breed true thereafter and produce only dwarfs when self-fertilized; the remaining 75 per cent. were tall. But the seed from these latter showed that approximately 25 per cent of them were of the dominant or "pure" tall variety, and like the dwarfs, bred true thereafter when kept separate and self-fertilized; and the remaining 50 per cent, though seemingly all tall were not really so, as they gave rise in the next generation to all three kinds again. That is to say "pure" dwarfs, "pure" talls and "impure" talls, appeared in the same proportion of 25 per cent. of each of the "pure' kinds and 50 per cent. of the "impure" kind; and further that this form of inheritance seemed to continue indefinitely from generation to generation thereafter. Mendel called this phenomenon the Law of Splitting or Segregation.

Since 1900 many experiments of a similar kind have been carried out upon plants and animals; from which we have learned that this law holds good in a large number of cases, but strangely fails to hold good in others. In other words, it is not universally applicable; all kinds and degrees of blendings of certain qualities or characters appearing in the progeny of crosses at times.

From these numerous exceptions to Mendel's law we can apparently draw but one conclusion, and that a very important and significant one, namely: that the characters appearing in an organism have measurable degrees of segregation and fixity, and therefore must be regarded as the outcome and direct result of the Evolutionary process; or, to speak more particularly, and in terms of the physical basis of heredity, the chromosomal elements show a tendency to combine in a definite manner and form more or less fixed and stable complexes.

Out of this tendency, by isolation, or the absence of disturbing influ-

ences, arising either from within or without the organism, we may see how those characters which distinguish one variety or race from another originate and, falling under the law of Segregation, become fixed; and thus how the distinctive and heritable characters of species arise.

If Mendel's law of Dominance were of universal application in the life-realm, then, indeed might the anti-evolutionists claim that it demonstrates the fixity of species. But we know it is far from doing this. A fairly long list of Mendel's unit characters, as they have been named, has been worked out, but a long list of others has also been found to lie outside his law of Dominance, characters which appear just as distinctive as those that are known to be segregated into "dominants" or "recessives," and which interfuse and blend into one another in all possible degrees of combination. Thus Galton found that certain characteristics of parents were invariably blended in the offspring; and everybody is familiar with this kind of blending and the fleeting, subtle likeness to both parents displayed at times by their offspring. Other familiar instances are the varying blendings of color in mulattos and Eurasians.

Castle bred long and flop-eared rabbits with short and erect-eared ones, and the resulting offspring bore ears of intermediate length and partial flop. By interbreeding these again he produced an intermediate strain with ears three-quarters of the length and flop of the original long and flop-eared variety.

Numerous other experiments of a similar kind in breeding and crossing have shown that Mendel's law is not only limited in its application in respect of the characters to which it applies, but that in many instances these characters themselves are impermanent, later breaking up and interfusing.

The Mendelian law, important as it undoubtedly is in all questions of inheritance, has, it is clear, by no means revealed all the secrets of heredity; much remains yet to be learned concerning it.

Mendel's greatest service to biology lay in his discovery of what de Vres termed the "unit characters" of organisms; the relative constancy and independence of these, when once they have appeared and become settled, throwing much light upon the way in which differentiations and types become fixed; thus making possible the evolution of new varieties, races and species.

To rightly understand Mendelism and how the laws of Dominance and Segregation work, one must learn something of the physical basis of heredity; in other words of the chromosomal mechanism by which heritable qualities and characters are passed on from one generation to another.

As already stated it is pretty universally conceded by modern biologists that those nuclear elements we call the chromosomes are the carriers of heredity, as they are also the determiners of sex. They appear to be the most important constituents of the substance making up the germ-cell. With rare exceptions these nuclear elements are found to be constant in number, and also characteristic of the species of organism possessing them. That is to say they exhibit a definite individuality; and it is out of this characteristic that the segregated "unit characters" of Mendel become possible, and new forms or species arise.

Many different organisms have exactly the same number of chromosomes in their cells, ranging from as few as two, up to hundreds; but are apparently alike in no other way. Thus man and the tobacco plant have each 48 chromosomes. But this fact seems to have no particular significance; their common possession of the same number of chromosomes would appear to be a pure coincidence.

We saw in an earlier chapter that the chromosomes were individualized aggregations of the chromatin matter in the germ-cell, the most definitely and highly organized of all its con-

tents. This chromatin is apparently made up of definite numbers of so-called chromomeres, which may run into the thousands in each germ-cell. It is from the associating or combining of these chromomeres or "factors" that the larger units, the chromosomes, arise.

In cell division, or mitosis, as we saw the process was termed in an earlier chapter, we find the chromosomes are, at a certain stage in the process, simply lines of chromomeres resembling strings of beads; each bead, as it were, corresponding to a separate chromomere. It would further appear also that each individual chromomere possesses distinct qualities or characters of its own, so that no two of them are ever quite alike; and each has also a definite position in the chromosomal complex which they together make up; and under normal conditions always occupies that place.

It is this definite localization and individualization of the chromomeres that makes possible the "unit characters" discovered by Mendel. These characters are clearly the result of definite and relatively constant groupings or aggragations of the chromomeres into chromosomal combinations or complexes in the germ-cell; each definite complex forming the material basis of a unit character.

Regarding the chromosomal compounds in this way it becomes fairly clear to us how the Mendelian unit characters arise, maintain their special qualities, and are passed on in inheritance.

It also explains how Mendel's law of Segregation is not of universal application, and why all degrees of blendings of parental characters may at times occur.

In the one case definite and relatively constant associations or combinations of the chromomeres have arisen, possibly under the operation of some law of chemical affinity or mutual attraction, and thus a relatively stable chromosomal complex has been established, and a unit character come into existence. In the other the chromomeres have evidently not yet become definitely segregated; the chromosomal complex has not yet been fully established, with the result that all possible combinations of the chromatin material take place, and all kinds of blendings and permutations come about.

It also explains equally well the appearance of new characters, in the de Vries' mutations, and the creation of new races and species of plants and fruits by Burbank.

Given the tendency of the chromosomes to combine after the manner of chemical elements into definite associations—and this must apparently be granted—then all the rest follows as a matter of course; and the Mendelian mechanism in all its phases—the relative constancy of unit characters; the limited applicability of the law of Segregation; and the sometime impermament nature of the unit characters—becomes explicable.

That Mendel's law of Segregation is one of the outcomes of the evolutionary process and has been gradually brought into operation, is shown in the first place by its limited applicability; and in the second, still more clearly, by the fact that we can experimentally break up the chromosomal complexes which form the physical bases of all organic characters and cause a re-combination, a new association of them; and thus the appearance of entirely new characters, and hence new races and species. Many well-known experiments make this quite clear.

Among these, probably the most conclusive, on account of their wide range and large number, are those which have been carried out by Burbank. His experiments in hybridization or crossing of stocks reveals to us, among other things, that Mendel's law of Segregation was more limited than Mendelians have generally thought; that when experiments such as his are carried out with large numbers of seedlings from the same crossing, the Mendelian ratios

are not closely maintained. More interfusions and permutations occur than the more restricted experiments usually employed by Mendelians reveal. Burbank's experiments sometimes involved the propagation of hundreds of thousands of individual specimens. He has been known to plant out as many as half a million seedlings to secure a single specimen which would blend in itself the ideal qualities or characters he aimed at establishing.

Burbank found also another important result emerging from his extended experiments. He learned that, notwithstanding the existence and operating force of Mendel's law of Segregation—which clearly tends to keep the chromosomal complexes, once established, intact and constant —these complexes and their resulting unit characters were greatly disturbed and sometimes completely broken up when two distantly-related species of plants were crossed; that the progeny of such crossings not only lost their typical unit characters and showed every kind of blending, but that also many wholly new, strange and even monstrous forms arose among the hybrids.

The implications here are exceedingly important and significant. They seem to make it not only quite certain that Mendel's unit characters have arisen under the evolutionary process out of the fundamental tendency of the chromatin in the germplasm to segregate itself into definite combinations or complexes; but that this tendency is checked; the chromosomal complexes broken up, and the unit characters resulting therefrom consequently disrupted, when strange and differing gametes or sex cells commingle; the resulting zygote or fertilized cell giving rise to new complexes and new characters.

Clearly, all advance in our knowledge of the evolutionary process, and the final solution of the problems of inheritance, lies in cytological investigations; that is, in the comparative study of the germ-cell and of those wonderful elements within its nucleus —the chromomeres and chromosomes.

As indicative of the increase in our knowledge that may follow such studies, some of the results reached by Otto Rosenberg in his cytological investigations as presented before he biological section of the British Association for the Advancement of Science at Toronto last summer, may be briefly mentioned. They will form an apposite conclusion to this short dissertation upon the "factors" of evolution.

He showed that in the study of the chromosomes we have a sound cytological basis for the production of new species of plants and animals by hybridization. His investigations appear to make clear how variations arise; what are their chief causes; and also why sterility frequently, though not as often as has been generally supposed, follows the crossing of stocks.

Both phenomena seem to have a common origin or like cause, namely: faulty or abnormal division of the germ-cell contents in mitosis. In other words, an unbalanced division of the chromosomes has come about. He tells us that a "pure" species is one in which the number of the chromosomes is always balanced or "diploid," that is, paired or doubled. Such a condition of things makes for stability of type and constancy of the Mendelian unit characters; while on the other hand an unbalanced number of chromosomes in a cell indicates a crossing or some other disturbance; and that this makes for instability of type and impermanence of these characters; and as a result variations, mutations or new forms are apt to arise.

Chief among the causes leading to this latter condition would appear to be the following: Crossing of stocks with different chromosomal numbers; irregular transversal division of the chromosomes instead of the normal longitudinal one; occasional end-to-end union between two

chromosomes, thus leaving less than the normal number in the cell; a similar diminution in numbers from fragmentation of some of the chromosomes, with a resulting coalescence of these fragments into a single large chromosome; and also incompatibility at times in the pairing chromosomes themselves.

These and other irregularities in mitosis or cell-division—all of which are probably caused by influences external to the cell itself, such as changes in environmental conditions; or the action of the secretions of the endocrine glands in the blood stream; or the crossing of distantly-related stocks—were shown to be potent causes which gave rise to variations and are capable of producing mutations and thus new forms.

We have an excellent illustration of the effect of environmental changes, for example, upon the chromosomal complexes, in de Vries' Evening Primrose. This plant was imported into Europe from America, and as a result gave rise to many different forms. Thus the original form, O. Lamarckiana, is characterized by fourteen chromosomes, but the mutants, O. lata, O. albida and O. sinctillans, derived from it, have each fifteen; while O. semi-gigas has twenty-one and O. gigas twenty-eight.

The only reasonable explanation of this change in the chromosomal numbers in these mutated forms is that it is due directly to changed environmental conditions.

In the light of these advances in our knowledge of the factors of evolution, we can confidently look forward to a time in the near future when the differences of opinion found at present among biologists regarding the causes underlying the evolutionary process will vanish and be no more; when the same unanimity of opinion will prevail among them concerning the "factors," as now exists in regard to the "fact" of organic evolution.

CHAPTER XXV.

Conclusion

IN THE foregoing chapters we have been considering the doctrine of organic evolution almost exclusively from the point of view of its basic or physical characters, and while it is true that evolution deals mainly with the material side of things and falls within the domain of the so-called physical sciences, there is, nevertheless, an aspect of evolution which is not explicable from this standpoint alone, and which transcends the power of the purely physical sciences to satisfactorily deal with. For while man is undeniably a product of the evolutionary process, there is much more to him than his material body; he is more than an organized assemblage of cells, wonderful as we have seen these units of life to be; and we have to go beyond physics to explain him in his entirety.

An extended meaning must, therefore, be given to the doctrine of evolution. For if evolution be that fundamental principle in the universe science teaches and we believe it to be, then it ought to account for every phase of man's being and not merely for his body. And this, when it is rightly understood and interpreted, it is competent to do.

Man, on his mental, and on his so-called moral and spiritual sides—and these aspects of his nature cannot be denied, they are no less a part of his being than his body—is as much the product of the evolutionary principle as he is on his corporeal side. Mental, moral and spiritual influences are just as real and demonstrable as physical ones—indeed, there are some philosophers who would say more so—and consequently there must be sources from which these influences emanate. The mental, moral and spiritual realms cannot be less real than the physical realm, for the evolutionary law is seen to be as active in them as in the other.

Man is as much environed by unfolding and formative influences from these regions as he is by those which operate in the physical world; and he is today just what we find him to be, mentally, morally and spiritually, by reason of their presence and force, and his response to their molding influences.

No one who has observed the growth and development of a child's mind, and seen the gradual emergence of its mental powers, can doubt that this side of its nature is any less the outcome of the evolutionary process than we have seen its body to be. Modern physico-psychology leaves no room for doubt that whatever may be the ultimate nature of consciousness, it is wholly dependent upon the nervous matter of the brain for its manifestations. There is an inter-relatedness of some kind between the brain and mental activity; and we know there can be no manifestation of mind if the integrity of this union or relationship be broken or seriously impaired.

The comparative study of intelligence, too, as it manifests itself in the animal world, has made it very clear that there is no essential difference between the intelligence of man and that of the creatures below him. Such differences as exist are those of degree only, and not of kind. He has reached a higher mental development than they. His brain is more complicated, more highly-organized than theirs, and, there-

fore, his intelligence is greater and more advanced.

If organic evolution has taught us any one thing more clearly than another, it is that, with the rise in the scale of being; with the advance in structure and function; with the growth and development of the brain and the complexity of the nervous system generally, there has been a fuller outpouring of the Psyche, an increased and higher manifestation of Mind.

And in the same way, nobody who has made a comparative study of morals, as they are found existing today among different peoples in different parts of the world, and as they have existed at other times in human history, can doubt that they are equally the product, and come under the dominance, of the evolutionary principle.

Morals are clearly the natural outcome of the social instincts of man, guided and formed in the first place by the light of his expanding intelligence, and later, when the spiritual side of him had sufficiently unfolded, by his spiritual discernment; and hence their intimate relation with religion.

The primary meaning of the very term "morals" itself makes this quite plain. We get it through the Latin word "mores," meaning manners or customs

It is fairly obvious that as soon as man had reached the social stage and lived in groups, communal customs, habits and manners would necessarily arise. If social relations were to become possible and tolerable, then conduct, social rules and regulations must be established and recognized.

History records many instances of this kind of establishment, of the deliberate formulation of such social codes or laws. Two notable examples readily come to mind—those of Moses for the Hebrews, and those of Hammurabi, the first king of the united countries of Akkad and Shumir, for the Babylonians.

There are no races so backward but have their social laws and regulations, their standards of conduct, or that have not imposed duties and obligations towards each other upon themselves, the breach or disregard of which meets with prompt condemnation and punishment. And the farther a people has advanced in civilization and the higher their culture, the more humane and enlightened will their laws and regulations be found to be; the loftier their conceptions of duty and obligation; the greater consideration and regard will they give to the rights and feelings of their fellows; the more exemplary will be their conduct and social relations, and the more keenly conscious and sensitive will they become of Right and Wrong, of actions that may or may not be done.

We are today in our moral characters and sensibility, individually, socially and nationally, as much the natural outcome and product of the standards of conduct we have lived under, of the moral environment by which we have been influenced and formed, in accordance with the responses we have made thereto, as our bodies are the natural product of the physical influences that have molded and made them what they are.

There has clearly been the same gradual unfolding, the same slow growth and development of the moral side of our nature as of the physical. The same gradual emergence of our moral consciousness as of our intelligence has taken place. All history bears witness to this. He who once rightly grasps and realizes this fact can never thereafter have any doubt about the existence of a moral world, or of moral influences surrounding and molding him.

Those who reject this view and question the existence of a moral realm from which can emanate those influences by which our moral consciousness has been aroused and developed, are faced with the difficulty of explaining the appearance and

evolution of the altruistic impulses we today find in man.

The law of the talon and the beak prevails in the world of Nature. She is still "red in tooth and claw." There Might is always Right, and the survival of the fittest means the survival of the strongest. The race there is always to the swift and the physically fit.

Altruism could never spring from the jungle, nor can we look there for deeds of heroism, for unselfish devotion to duty, for compassion, tenderness or pity. The world of Nature knows nothing of such; nothing of mercy and loving kindness; nothing of sympathy for the helpless and the weak, nor of the many other virtues we term moral. It is not in the jungle these flourish; we must look elsewhere for their use and origin.

We are thus logically driven to postulate a moral realm, a source or region apart from the physical world, to account for these aspects of man's nature and for the altruistic impulses or principles he manifests. And the very fact that individuals and communities, races and peoples, differ greatly on these sides of their character; possess high or low ideals of conduct, show little or much consideration for the rights and feelings of others; are selfish or unselfish; egoistic or altruistic, and exhibit all degrees of moral consciousness and sensibility, makes it quite clear that the moral sides of our nature are as much the outcome of the evolutionary principle as our physical sides.

And if we find it impossible to imagine the moral qualities displayed by man at his best arising from the jungle, it becomes still more impossible to regard those higher sides of his nature we are accustomed to call "spiritual" as having such a source or as being the product of physical forces.

We are, therefore, driven again by logical consistency to postulate a realm from which they might be conceived to have emanated. It is as impossible to deny spiritual influences and spiritual experiences in our lives as to deny physical influences and sensuous experiences. The one is no less real than the other. The spiritual realm must, therefore, be as actual as the physical. If man be today the three-fold being we think and believe him to be, then he must be the product of a three-fold environment; there must of necessity be a moral and a spiritual realm as well as a physical.

Again, the very fact that we experience spiritual longings, have spiritual aspirations, feel spiritual needs, seek and find spiritual satisfactions, proves to us the existence of a spiritual world. These cannot be found in or got out of a physical realm. Religion and religious experiences—and these also cannot be denied—would be meaningless if there were no spiritual realm to give them significance, and their very universality is proof of their deep reality and of a source from which they must come. Wherever man is found, no matter what his state of culture, high or low, we find he is a religious being, that he has religious needs and seeks to satisfy them. And the very fact that the outward forms of his religion differ so widely from age to age and from people to people, makes it quite clear that we develop spiritually just in the same gradual and progressive way as we do morally and physically.

To regard religion, as some do, as having no value except as a means to morality, is to woefully misunderstand the religious instinct in man. It is true that morals have very generally received their sanction from religion, and the two are inextricably interwoven; yet the primary function of religion is obviously to deal with the spiritual side of man. Religion develops his spiritual nature; evokes his spiritual consciousness; facilitates and opens the way for spiritual communion and

supplies his spiritual needs, and the more spiritual he is, the more moral will he be. True, the forms of religion are manifold and protean. This could not be otherwise, seeing that man is a product of the evolutionary law on his spiritual as on his moral and physical side; and we are not all equally developed spiritually, nor have all reached the same degree of spiritual discernment. No better evidence could be offered of the slow evolutionary growth of man's spiritual nature than the myriad forms under which his religious instincts have manifested themselves and the childish and imperfect conceptions he has formed of the nature and character of the Deity. But though the forms of religion are many and changeful, and though they have not always tended to the true development of man's spiritual nature, have, indeed, often hindered and retarded it, the spirit of religion is one and everywhere the same.

The religious instinct, therefore, is by its very presence and universality evidence of a not inconsiderable kind of man's spiritual nature and his spiritual needs.

No one who has given thought to the matter can deny that man has a sense of reality other than that given him by the senses. We all at times have experiences more or less mystical which cannot be explained rationally, which transcend the mind and reason and must therefore have a source other than a sensuous one. There must be a spiritual world to account for our spiritual experiences, especially for those deep and transforming ones, the effects of which are readily perceived in the lives of those who have undergone them; those mystical experiences which leave an abiding consciousness and certitude of the Divine, and a tranquil, satisfying sense of union with the Absolute, that nothing thereafter seems able to efface or disturb.

The facts of immediacy, as James calls these mystical spiritual experiences, even though we may ourselves never have experienced them, have received the attestation of too many great souls for us to doubt their reality or question their existence. Their reality must perforce be admitted.

Nor do these instances of the spiritual life by any means exhaust the arguments in favor of the existence of a spiritual realm. Other lines of evidence offer themselves, such, for example, as spiritual exaltations, intuitions, and the sometimes remarkable uprushes of genius. Not one of these phenomena is explicable in terms of physics, nor can they be rightly said to have their source in a physical realm.

Seeing, then, that the doctrine of Evolution teaches and proclaims, when it is rightly understood and interpreted, that man is as much a moral and spiritual being as he is a physical one; that a moral and spiritual world with moral and spiritual influences must exist in order to satisfactorily explain these sides of his nature, Mr. W. J. Bryan and other Fundamentalists are guilty of perverting the truth and misleading their followers when they assert, as they so often do, that a belief in Evolution leads to irreligion, immorality, a denial of God, of a spiritual life and of a spiritual world. It should be clear from what has been said that nothing can be farther from the truth. The facts of science as given in the doctrine of organic evolution lead rather to a confirmation, when rightly comprehended, of one's belief in a Creator, a Director and Controller of the Universe. The God of the evolutionist may not be —indeed He could not be—that incredible, anthropomorphic, implacable Being of whom the earlier Hebrew Scriptures speak, and whom Mr. Bryan would impose upon us and have us worship.

If the evolutionist attempts to conceive of the character of the Creator at all—and mostly he does not, being only too conscious of the

limitations of the human understanding and the futility of trying to comprehend the Incomprehensible—he does it by the study of his handiwork, feeling that if the Omnipotent has anywhere made a revelation of Himself to man it will be in the Book of Nature. He will be found there as surely and as truly as in the Hebrew or any other Scriptures, concerning the authorship and history of which so much uncertainty exists in the minds of those who have studied their contents, and are deemed best capable of judging of their reliability and veracity.

It is not the doctrine of Organic Evolution that takes our young people away from the churches and leads them to give up their religion and their belief in God. It is rather the attitude of such churchmen as Mr. Wm. J. Bryan, who seek to impose upon them doctrines and beliefs their reason tells them cannot be true, and against which their intelligence revolts.

It would be amusing, were it not so lamentably pathetic, to see men of intelligence like Mr. Bryan, and the other leaders of the anti-evolutionist movement—and no one seriously questions their general intelligence, though one may wonder at their obtuseness and perverted vision—trying to impose upon the young minds of this age the worn-out, antiquated theology and beliefs of less enlightened times, and which the vast majority of the great religious organizations of our day have long since discarded.

Our young college people scoff at the medieval ideas held and advocated by the Fundamentalists of today. They marvel that any intelligent being can any longer hold to the literal interpretation of the so-called Mosaic story of Creation. No wonder they think religion is something for undeveloped children or people of weak intellects, when they are seriously asked to believe that every word of the Hebrew scriptures was inspired and dictated by God—that the story of Jonah and the whale, the standing still of the sun and the moon during the battle of Gibeon and numerous other obviously fabulous portions, must be accepted literally and regarded as having a divine origin; that the world and all upon it first came into existence a bare six thousand years ago; that the first man was literally made from the dust of the earth and the first woman from one of his ribs; that they were turned out of a literal garden of Eden, and all their progeny thereafter eternally damned because Eve one day thought the fruit of a certain tree looked inviting and plucked therefrom an apple at the instigation of a literal serpent, who told her in literal language (Hebrew of course) that its eating would make them as wise as gods; and afterwards gave the apple to Adam, who straightway ate it. How can they be expected to believe such obviously mythical statements and accept them as revelations of God.

The Old Testament is a unique and unequalled set of writings, the invaluable record, in the main, of the spiritual evolution of a people. But to declare that every part of it has been directly inspired by God, and must be accepted literally, is surely to ask one to stultify and mock one's reason, and to become guilty of that very idolatry against which it so often thunders. Bibliolatry, or worship of the Bible, is no essential part of religion in spite of Mr. Bryan's belief that it is; and it is this very insistence by the Fundamentalists that we must hold every jot and tittle of it, sacred and divine, that causes so many of our young people who have passed through an academic training, to give up their religion, stay away from the churches and lose their faith in the existence of a personal God.

It is not science nor a belief in the evolutionary doctrine, if Mr. Bryan could only be brought to realize it, but the intolerance, bigotry and narrow-mindedness of such churchmen as himself, that makes unbelievers and atheists of our young people of today. They refuse to stultify their reason, and their intellect; and as

religion has become associated, in their minds, with childish and irrational stories and beliefs, they will have none of it, and so drift away from the churches. The writer knows whereof he speaks and but expresses their sentiments in this regard.

Science and religion, as such, are not, nor can they ever truly be, in opposition to each other; nor can the organized knowledge of science ever conflict with statements from the bible, when these latter are truly inspired of God. Conflict can only arise between them when values and interpretations have been given to them which rightly do not belong to them.

Truth has been arrived at on the one side objectively; on the other subjectively. The modes are different but the result must be the same Truth never conflicts with itself whether it comes to us through the processes of reason or through the intuitions of the soul. Never let us forget that; and let us avoid the pitfalls both Scientists and Fundamentalists are equally prone to fall into, namely the over-emphasising of their own particular mode of inquiry or search to the exclusion or disregard of that of the other. The objective methods of science and the subjective methods of religion are equally avenues by which we may reach Truth and see God. They should therefore, ever supplement each other and never be brought into conflict.

ERRATA

On page 32, in the last paragraph but one, after "the earth's age," read in: "As science can reach at the present time, we may conclude that life in."

On page 58, read "severed" for "several" in the 34th line in right-hand column.

On page 65, read "of" for "to" in the first line in right-hand column.

On page 101, read "chapter" for "article" in 10th line in left-hand column.

On page 149, read "impermanent" for "impermament" in line 24 in right-hand column.

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